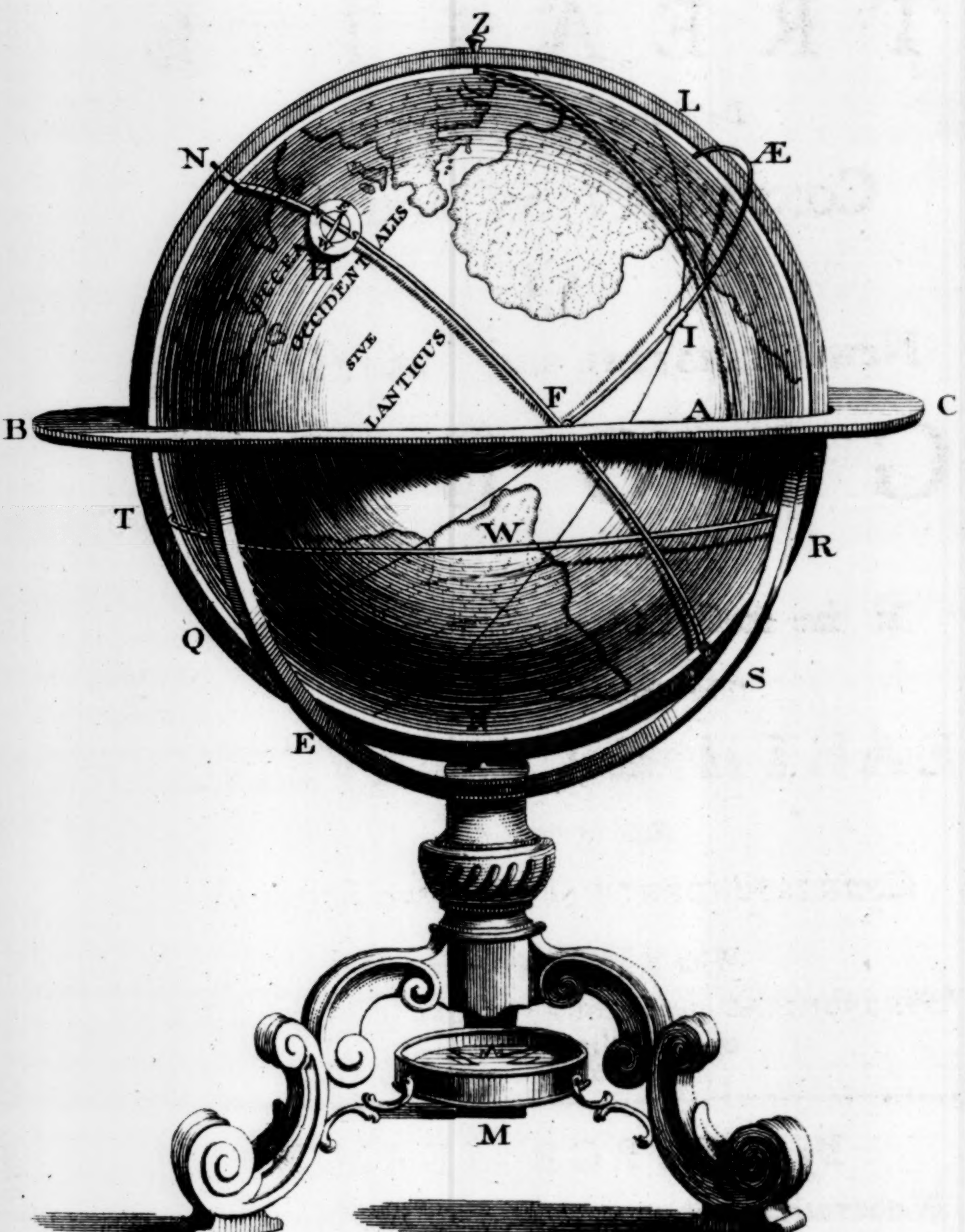
Plate I. *To Front the Til*



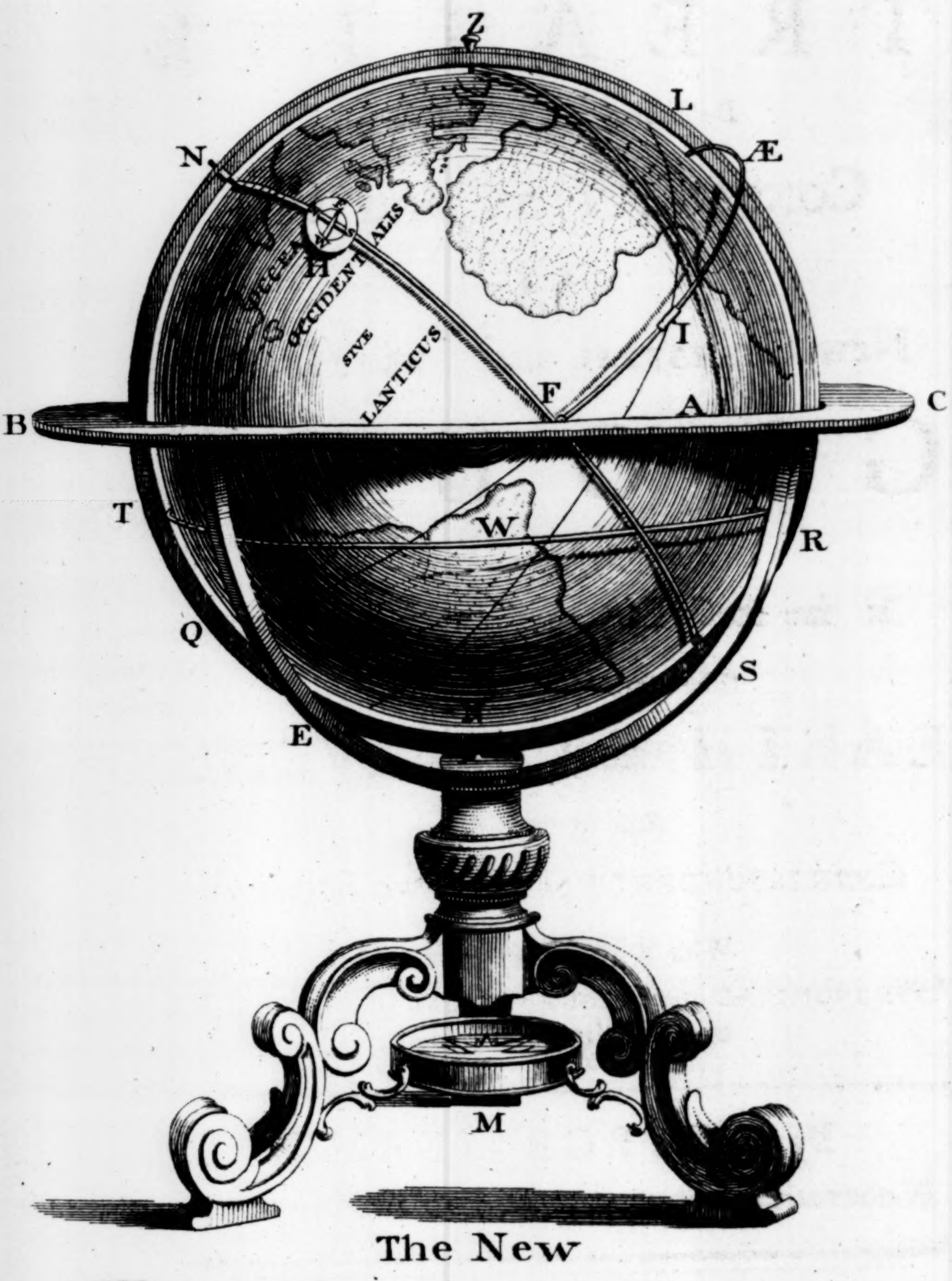
The New

TERRESTRIAL GLOBE,

As Improved and Constructed by GEO: ADAMS

In Fleet Street LONDON.

Plate I. *To Front the Til*



The New
TERRESTRIAL GLOBE,
As Improved and Constructed by GEO: ADAMS
In Fleet Street LONDON.

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A TREATISE

Deſcribing and Explaining the

CONSTRUCTION and USE

OF

New CELESTIAL and TERRESTRIAL

GLOBES.

Deſigned to illuſtrate,
In the moſt Eaſy and Natural Manner,
The PHOENOMENA of the
EARTH and HEAVENS,
And to ſhew the
CORRESPONDENCE of the TWO SPHERES.

With a great VARIETY of
ASTRONOMICAL and GEOGRAPHICAL PROBLEMS
occaſionally interſperſed.

By GEORGE ADAMS,
Mathematical Inſtrument-Maker to His MAJESTY.

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6

LONDON:
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BRAHE's Head, in Fleet-Street.

M.DCC.LXVI.

MVSEVM
BRITA
NICVM

TO THE

KING.

MVSEVM
BRITAN
NICVM

SIR,

IT is the privilege of real greatneſs not to be afraid of diminution by condeſcending to the notice of little things; and I therefore can boldly ſolicite the patronage of Your MAJESTY to the humble labours by which I have endeavoured to improve the inſtruments of ſcience, and make the globes on which the earth and ſky are delineated leſs defective in their conſtruction, and leſs difficult in their uſe.

Geography is in a peculiar manner the ſcience of Princes. When a private ſtudent revolves the terraqueous globe, he beholds a ſucceſſion of countries in which he has no more intereſt than in the imaginary regions of Jupiter and Saturn. But Your MAJESTY muſt contemplate the ſcientifick picture with other ſentiments, and conſider, as oceans and continents are rolling before You, how large a part of mankind is now waiting on Your determinations, and may receive benefits or ſuffer evils, as Your influence is extended or withdrawn.

The provinces which Your MAJESTY's arms have added to Your dominions, make no inconſiderable part of the orb allotted to human beings. Your power is acknowledged by nations whoſe names we know not yet how to write, and whoſe boundaries we cannot yet deſcribe. But Your MAJESTY's lenity and beneficence give us reaſon to expect the time when ſcience ſhall be advanced by the diffuſion of happineſs; when the deſarts of America ſhall become pervious and ſafe, when thoſe who are now reſtrained by fear ſhall be attracted by reverence; and multitudes who now range the woods for prey, and live at the mercy of winds and ſeaſons, ſhall by the paternal care of Your MAJESTY enjoy the plenty of cultivated lands, the pleaſures of ſociety, the ſecurity of law, and the light of Revelation.

I am,

SIR,

YOUR MAJESTY'S

moſt humble,
moſt obedient,
and moſt dutiful,
Subject and Servant,

GEORGE ADAMS.

PREFACE.

THE connection of aſtronomy with geography is ſo evident, and both in conjunction are ſo neceſſary to a learned education, that no man will be thought to have deſerved ill of the republic of letters, who has applied his endeavours to throw any new light upon ſuch uſeful ſciences. And as the phenomena of the earth and heavens can be adequately illuſtrated only by the mechanical contrivance of globes; whatever improvement is made in theſe muſt deſerve regard, in proportion as it facilitates the attainment of aſtronomical and geographical knowledge.

As to maps and all projections of the ſphere in plano, their uſe is more difficult than thoſe of the globe, of which indeed they are only ſo many pictures; nor can they be thoroughly underſtood without more ſkill in geometry than is commonly poſſeſſed by beginners, for whoſe uſe the following treatiſe is principally deſigned; tho' it alſo contains ſome obſervations, which I hope will not be altogether unacceptable to a more learned reader.

The globes now offered to the public, are of a conſtruction new and peculiar, being contrived to ſolve the various phenomena of the earth and heavens, in a more eaſy and natural manner than any hitherto publiſhed, being ſo ſuſpended that the ſtudent may elevate the ſouth pole; a thing impracticable in the uſe of the common globes.

That agreement too, which is here pointed out between the celeſtial and terreſtrial ſphere, will be found to open a large field of geographical and aſtronomical knowledge; and will afford both inſtruction and amuſement to every unprejudiced enquirer. This agreement ariſes from a compariſon of one globe with the other, or of the diſtances of different places on the earth's ſurface, with the relative diſtances of ſuch fixed ſtars as anſwer to them in the heavens.

By theſe ſteps of ſcience, the mind of man may be raiſed to the contemplation of the divine wiſdom, which has ſo adjuſted the proportion of days, months, ſeaſons, and years, in the different parts of the terraqueous globe, as to have diſtributed with an impartial hand, though after a manner wonderfully various, an equal ſhare of the ſun's light to every nation under heaven.

By theſe globes, with little or no experience in aſtronomy, may be ſeen how the moon changes her place every night, by obſerving her poſition with reſpect to any fixed ſtar, and how ſhe proceeds regularly from it to the eaſtward; as the ſeveral planets alſo may be obſerved to do, ſome more ſlowly than others, as their orbits are more or leſs remote from the center of the ſyſtem; while the regularity of their motions, ſtrictly conformable at all times to the laws of their Creator, exhibits a ſtriking pattern of obedience to every rational ſpectator.

But it will be proper in this place to inform the reader what he is to expect in the globes, and in the following treatiſe intended to accompany and explain them.

The ſuperior accuracy with which the plates are drawn and engraved, will, it is hoped, appear to competent judges at the firſt ſight; for the perfecting of which no expence of time or labour hath been ſpared. The celeſtial globe is improved by the addition of ſeveral thouſand ſtars more than have appeared upon any globe hitherto publiſhed; all the lateſt diſcoveries in geography and aſtronomy are in both of them ſtrictly followed, and many new lines and circles are inſcribed, the uſe of which will be fully explained hereafter.

In the treatiſe, we have made choice of that method of finding the times of equinox, which is the moſt modern and ſimple; and which perhaps is the trueſt mean length of a tropical year; that the young ſtudent may with greater eaſe and pleaſure be made acquainted with the firſt principles, and from them be carried on to the more intricate branches of aſtronomy.

The table of the paſſage of the firſt point of aries over the meridian, is taken from an Ephemeris of La Caille, with ſome little alterations; and has been carefully compared with twenty years calculations made by the ſame author. The neceſſity under which I found myſelf of haſtening the publication of this Treatiſe, and the various interruptions and avocations from which a perſon in my ſtation cannot be exempt, would not allow me ſufficient leiſure to calculate an original table.

To render this book as extenſively uſeful as poſſible, I have endeavoured, with all the clearneſs I am maſter of, to expreſs both my own and the ſentiments of other authors on the ſame ſubject; and I think it my duty to acknowledge the aſſiſtance I have received in the courſe of this work, as well from books, as from ſome worthy friends; as I would not willingly incur the imputation either of plagiariſm or ingratitude. If there ſhould appear to be any defects, to which every human work is liable, the reader, I hope, will make ſome favourable allowance for the undertaker of a taſk ſo complicated and laborious, and correct my errors for himſelf, as well as he is able.

ADVERTISEMENT.

When the reader is hereafter directed to apply a card, or the edge of a card, to any part of the globe, it is to be underſtood that he ſhould cut a card of any kind exactly in the ſize and ſhape of A B C D, fig. 4. for the globes of eighteen inches diameter; and of the ſize and ſhape of E F G H, for thoſe of twelve inches diameter; then, if the arch B C, or F G, are applied to the ſurface of their reſpective globes, the lines A B, or C D, E F, and G H, will become radii from the center of the globe. It is frequently required to know what point upon the ſtrong braſs meridian, or broad paper circle, exactly anſwers to a given point upon the globe, and as this cannot be well known by inſpection, on account of the neceſſary diſtance of theſe two circles from the ſurface, if the corner B or F be applied to the given point upon the globe, the edge of the card will exactly mark the degree or part of the degree required.

For elevating the pole exactly, the card is to be laid upon the broad paper circle, and its edge applied to the ſtrong braſs meridian; by which means the degree, and parts of a degree, may be aſcertained with ſufficient accuracy.

The explanation of the letters to the figures 1 and 2.

Fig. 1. repreſents the new terreſtrial, and fig 2. the new celeſtial globe, with their improved apparatus.

N Æ R Z N. The ſtrong braſs meridian.

N H S. The thin braſs ſemi-circle, or moveable meridian, upon the terreſtrial, but upon the celeſtial globe it is a moveable circle of declination; on the firſt of theſe is placed H a ſliding circle, which is hereafter called an artificial horizon; the little ſliding circle upon the celeſtial globe, is called an artificial ſun.

Æ I Q. The equator, over which in either figure is repreſented about half of the ſemicircular wire F I Æ, which carries the horary indices, one of them is ſeen at I.

E L. The ecliptic

Z A. The braſs quadrant of altitude ſcrewed faſt to Z, the zenith point of the ſtrong braſs meridian, its other end, A, going a little below the plane of

B A C. The broad-paper circle upon the ſurface of the wooden frame.

T W Y. The wire circle, repreſenting the boundaries of twylight.

N C S.

N C S. A ſilk ſtring, fig. 2. fixed occaſionally to the north and ſouth poles of the celeſtial globe, which is hereafter deſcribed, and called an artificial moon; it may alſo repreſent the place of any planet.

M. The mariner's compaſs, with a magnetic needle.

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Ellis's Microſcope	2	2	0
A ſolar Microſcope	4	14	6
Ditto	5	15	6
A Microſcopical Apparatus in a Mahogany Box	12	12	0
all other Sorts of Microſcopes at the uſual Prices.			
A Pocket Camera Obſcura	0	10	6
Ditto	1	1	0
Ditto, large	1	5	0
Ditto, larger	2	2	0
A Book Camera, of a new Conſtruction	5	5	0
A new Inſtrument for taking Perſpective Views	6	6	0
Concave and Convex Mirrors, from *7s. 6d.* to	26	0	0

Priſms,

	l.	*s.*	*d.*
Priſms, from *7s. 6d.* to	2	2	0
Zograſcopes for viewing Prints, from 18*s.* to	2	12	6
Opera Glaſſes, from 8*s.* to	1	1	0
Reading Glaſſes, from 2*s.* 6*d.* to	3	3	0
Spectacles for the Noſe	0	1	0
Ditto for the Temples	0	3	0
Ditto	0	5	0
Ditto	0	7	6
Ditto, in Silver	0	14	0
Ditto, Double Joints which neither preſs the Noſe, or Temples	0	9	0
Ditto	0	12	0
Ditto, in Silver	1	1	0
Spectacles of Brazil Pebbles, in Steel or Silver, at the uſual Prices.			

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Air Pumps, excluſive of any Apparatus			
A ſingle Barrel ditto	2	2	0
A ſmall double Barrell'd ditto	4	4	0
A ditto larger	6	6	0
A large Table Air Pump	10	10	0
A large Standing Air Pump	21	0	0

the Apparatus to either of theſe according to the Deſire of the Purchaſer.

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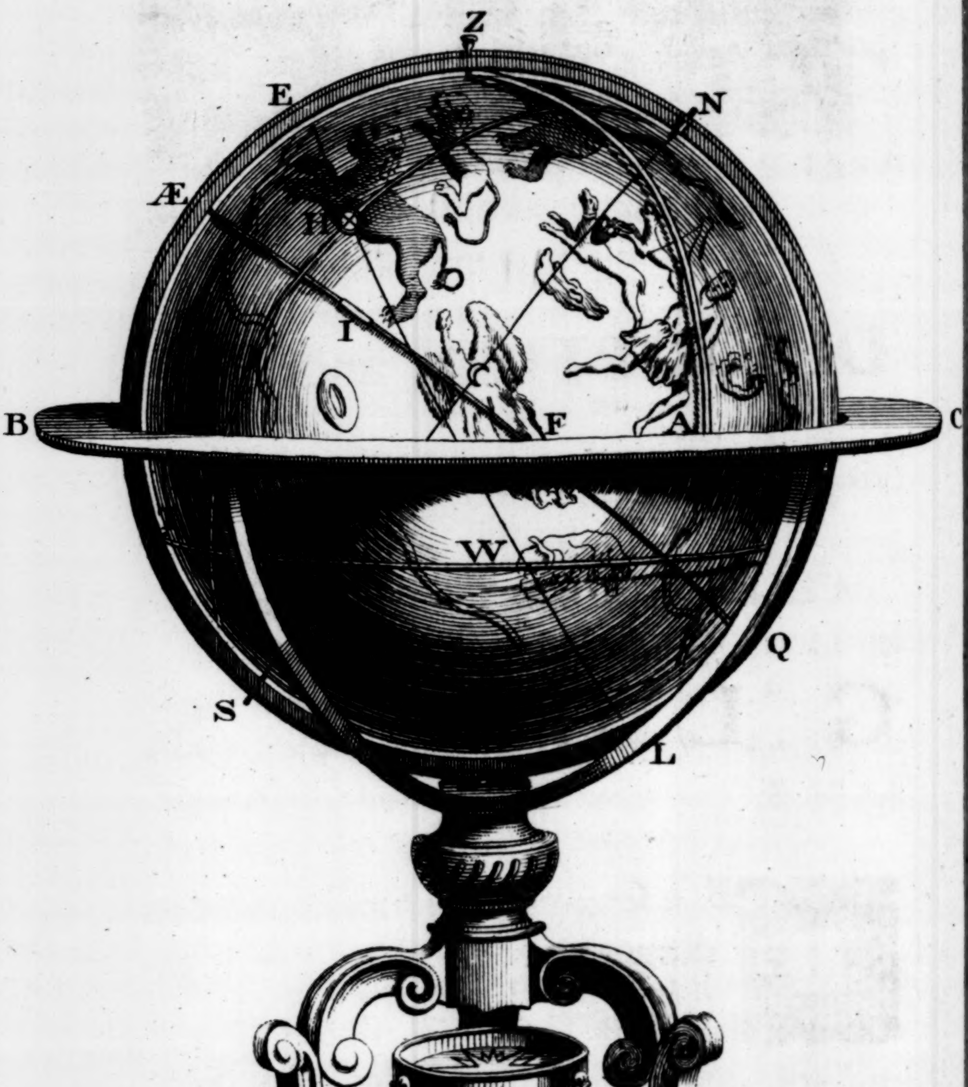
	l.	*s.*	*d.*
Barometers	2	2	0
Ditto, with Thermometers	2	12	6
Ditto	5	5	0
Ditto, with Hygrometers	5	15	6
A new invented Barometer of a peculiar Make	7	7	0
Diagonal Barometers	5	5	0
Wheel Barometers	8	8	0
Triple Diagonal Barometers	16	16	0
Botanick Thermometers	0	10	6
Ditto	0	18	0
Farenheit's Pocket Thermometers	1	1	0
——— Thermometers for Brewing, Diſtilling, &c.	1	11	6
Electrical Machines	6	6	0
Ditto	10	10	0
Hydroſtatic Ballances	2	12	6

A new and curious Hydrometer is now in Hand, of which the Price cannot be yet aſcertained.

Theſe, with all the Variety of Inſtruments required in the Practice of the ſeveral Branches of the Mathematicks, Philoſophy, and Optics, are Made and Sold as above, at the moſt Reaſonable Prices.

Plate II.

To Fr



The New

CELESTIAL GLOBE,

As Improved and Constructed by GEO: ADAM

In Fleet Street LONDON.

THE
DESCRIPTION and USE
OF THE NEW
CELESTIAL and TERRESTRIAL
GLOBES.

If a ſemi-circle be turned round its diameter as an axis, it will generate the ſurface of a globe or ſphere, and the center of the ſemi-circle will be the center of the globe: it therefore follows, that as all the points in the circumference of the ſemi-circle, are at an equal diſtance from its center, ſo all the points of a globe, thus generated, muſt be the ſame.

2. Any ſtrait line paſſing through the center of a globe, being terminated by its ſurface, is called a *diameter*; and that diameter about which the globe turns, is called its *axis*; the extremities of which are called the *poles* of the globe.

3. There are two *artificial globes*. That on which the ſurface of the earth is repreſented, is called the *terreſtrial globe*.

4. The other on which the face of the ſtarry ſphere is delineated, is called the *celeſtial globe*.

5. In the *uſe of the terreſtrial globe*, we are to conſider ourſelves ſtanding upon ſome part of its ſurface, and that its motion repreſents the *real diurnal motion of the earth*, which is from *weſt* to *eaſt*.

6. In the *uſe of the celeſtial globe*, we are to ſuppoſe ourſelves at the *center*, and that its motion repreſents the *apparent diurnal motions of the heavens*, which is from *eaſt* to *weſt*.

7. Note, The ſtars being delineated upon the convex ſurface of the celeſtial globe, we muſt ſuppoſe ourſelves at the *center*: becauſe under ſuch a ſuppoſition they would

appear as they naturally do in the concave ſurface of the heavens.

8. Several circles are deſcribed upon the ſurface of each globe. Thoſe whoſe planes paſs through the center of the globe, are called *great circles*; ſome of which are graduated into 360 degrees, 90 of which make a quadrant.

9. Thoſe circles whoſe planes do not paſs through the center of the globe, are called *leſſer circles*.

10. Our new *terreſtrial* and *celeſtial globes* are each of them ſuſpended at their poles in a ſtrong braſs circle, and turn therein upon two iron pins, which are the axes of the globe. They have each a *thin braſs ſemi-circle* moveable about the poles, with a ſmall thin ſliding circle thereon.

11. On the terreſtrial globe this ſemi-circle is a *moveable meridian*, and its ſmall ſliding circle, the *viſible horizon* of any particular place to which it is ſet. But,

12. On the celeſtial globe this ſemi-circle is a *moveable circle of declination*, and its ſmall circle an *artificial ſun* or *planet*.

13. Each globe hath a braſs wire circle, placed at the limits of the *crepuſculum*, or

twilight.

twilight, which, together with the globe, is ſet in a wooden frame, the upper part of which is covered with a broad paper-circle, whoſe plane divides the globe into two hemiſpheres, and the whole is ſupported upon a neat pillar and claw, with a *magnetic needle* in a compaſs box.

14. On our new terreſtrial globes, the *delineation* of the face of the earth into land and water, is accurately laid down from the lateſt and beſt aſtronomical, geographical, and nautical diſcoveries. There are alſo many additional circles, as well as the *rhomb-lines*, for the greater eaſe and convenience in ſolving all the neceſſary geographical and nautical problems.

15. On the ſurface of our new celeſtial globes, all the *ſouthern conſtellations*, lately obſerved at the Cape of Good-Hope by M. *de la Caille*, and all the ſtars in Mr. *Flamſted*'s Britiſh Catalogue, are accurately laid down, and marked with Greek and Roman letters of reference, in imitation of *Bayer*. Upon each ſide of the ecliptic are drawn *eight parallel-circles* at the diſtance of one degree from each other, including a ſpace of ſixteen degrees, called the *zodiac*; theſe are

croſſed at right angles, with ſegments of great circles at every fifth degree of the ecliptic, for the readier noting the place of the moon or any planet upon the globe.

16. We have alſo inſerted from *Ulugh Beigh*, printed at Oxford, A. D. 1665, the *manazil al kamer*, i. e. the manſions of the moon of the Arabian Aſtronomers; which are ſo called, becauſe they obſerved the moon to be *in* or *near* one of theſe every night during her monthly courſe round the earth, to each of which the Arabian characters are affixed. They may be of very great uſe to beginners to teach them the names of the ſtars, as well as to mariners for the ſame purpoſe; who may have occaſion to obſerve the diſtance of the moon from a fixed ſtar, in the new method of diſcovering the longitude at ſea. They will likewiſe ſerve to ſhew, how the moon paſſes from ſtar to ſtar in the courſe of one or ſeveral nights, which is a very curious and uſeful amuſement; and as they are a diviſion of the heavens different from any thing the Greeks were acquainted with, and therefore not borrowed from them, and as we do not know they were ever inſerted

on any globe before, we hope we have with propriety placed them on our new celeſtial globe.

The broad paper-circle on the ſurface of the wooden frame

17. Contains four concentric circular ſpaces. The innermoſt of which is divided into 360 degrees, and numbered into four quadrants, beginning at the eaſt and weſt points, and proceeding each way to 90 degrees at the north and ſouth points; theſe are the four cardinal points of the horizon. The ſecond circular ſpace contains, at equal diſtances, the thirty-two points of the mariner's compaſs. Another circular ſpace is divided into twelve equal parts, repreſenting the *twelve ſigns* of the zodiac; theſe are again ſubdivided into 30 degrees each, between which are engraved their names and characters. This ſpace is connected with a fourth, which contains the kalendar of months and days; each day, on the new eighteen inch globes, being divided into four parts, which expreſs the four cardinal points of the day, ac-

cording to the Julian reckoning; by which means the ſun's place is very nearly obtained for the three common years after biſſextile, and the intercalary day inſerted without confuſion. Whence we derive the following

PROBLEM I.

To find the ſun's place any day in the year on the broad paper-circle.

18. Conſider whether the year in which you ſeek the ſun's place, is biſſextile, or the firſt, ſecond, or third year after.

19. If it be the firſt year after biſſextile, thoſe diviſions to which the numbers for the days of the month are affixed, are the reſpective days for each month of that year at noon; oppoſite to which, in the circle of twelve ſigns, is the ſun's place.

20. If it be the ſecond year after biſſextile, the firſt quarter of a day backwards, or towards the left hand, is the day of the month for that year, againſt which, as before, is the ſun's place.

21. If it be the third year after biſſextile, half a day backwards is the day of the month for that year, oppoſite to which is the ſun's place.

22. If the year in which you ſeek the ſun's place is biſſextile, then three quarters of a day backwards is the day of the month from the winter-ſolſtice to the 28th day of February incluſive. The intercalary or 29th day, is three fourths of a day to the left hand from the 1ſt of March; and the 1ſt of March itſelf is one quarter of a day forward, from the diviſion marked 1; and ſo for every day in the remaining part of the leap-year; againſt each of which is had the ſun's place.

In this manner the intercalary day is very well introduced every fourth year into the kalendar, and the ſun's place very nearly obtained according to the Julian reckoning. Thus:

A. D.	Sun's place, April 25.
1769. firſt year after biſſextile	♉ : 5° : 21′
1770. ſecond - - - - - - - - -	♉ : 5° : 06′
1771. third - - - - - - - - - -	♉ : 4° : 55′
1772. biſſextile - - - - - - -	♉ : 5° : 35′.

22. One uſe of the broad paper-circle is to diſtinguiſh the points of the horizon; in which caſe it repreſents the *real horizon* of any particular place.

23. Another uſe we ſhall make of this circle is to repreſent the *circle of illumination*, or that circle which ſeparates day from night.

24. A third uſe to which this circle may be applied, is to repreſent the *plane of the ecliptic*. All of which ſhall be illuſtrated in their proper places.

25. In all poſitions of the celeſtial globe this broad paper-ſurface is the plane of the horizon, and diſtinguiſhes the viſible from the inviſible part of the heavens.

26. The north-ſide of the wooden frame ought to be placed directly towards the north-ſide of the heavens, which is readily done by the mariner's compaſs under our new globes.

The ſtrong braſs circle, or meridian.

27. There are two notches in the broad wooden circle, upon the plane of which the

broad paper-circle is placed, which receive the ſtrong braſs circle: the body of the globe being ſuſpended at two oppoſite points in this circle, turns round therein on its iron poles, one of which repreſents the *north* and the other the *ſouth-pole*.

28. One ſide of this ſtrong braſs circle is graduated into four quadrants, each containing 90 degrees. The numbers on two of theſe quadrants increaſe from the equator towards the poles; the numbers on the other two increaſe from the poles towards the equator.

29. The ſtrong braſs circle of the celeſtial globe is called the *meridian*, becauſe the ſun's center is directly oppoſite thereto at noon.

30. On the ſtrong braſs circle of our new terreſtrial globe, and about 23½ degrees on each ſide of the north-pole, the days of each month are laid down according to the ſun's declination; and this braſs circle is ſo contrived, that the globe may be placed in the poſition of a direct or right ſphere, (which is, when the north and ſouth-poles are placed in the plane of the broad paper-circle) and alſo that the ſouth-

pole may be elevated above the plane of the broad paper-ſurface, with as much eaſe as the north-pole. A circumſtance which we thought not unworthy of our attention in the conſtruction of our new globes.

31. The graduated ſide of the ſtrong braſs circle, encompaſſing our new terreſtrial globe, faces the weſt.

32. But that which ſurrounds the celeſtial globe, faces the eaſt.

33. In all inclinations of either globe, their north-poles ſhould be directed towards the north-point of the heavens, which the mariner's compaſs placed under each of the globes, will enable us to do with the greater readineſs.

The horary circle.

34. We uſe no other circle to meaſure the hours and minutes of time, but the equator upon the ſurface of either globe; it not only being the moſt natural, but the largeſt circle that can poſſibly be applied for that purpoſe. This is done by a ſemi-circular wire placed in the plane of the equator, carrying two indices;

one of which is occaſionally to be uſed to point out the time.

As the firſt meridian in our new globes paſſes through London, it therefore becomes the XII o'clock hour-circle; and this falls upon the interſection of the equator and ecliptic at the firſt point of aries; the other XIIth hour-circle paſſes through the oppoſite interſection at the firſt point of libra.

Alſo remember, when the globe ſhall be hereafter rectified for London, or any other place, on the ſame meridian with it, that then the graduated ſide of the ſtrong braſs meridian is the horary index itſelf.

Likewiſe it may happen, the globe ſhall be ſo rectified as that the two points of XII o'clock will fall in or ſo near the eaſt and weſt-points of the broad paper-circle that neither of the horary indices can be applied thereto; therefore either of theſe points themſelves will then be the horary index in ſuch a caſe.

35. The hours and minutes are graduated below the degrees of the equator on either globe; and as

36. The motion of the terreſtrial globe is from weſt to eaſt, the horary numbers increaſe according to the direction of that motion.

37. The motion of the celeſtial globe being from eaſt to weſt, the horary numbers increaſe in that direction.

The thin braſs ſemi-circle.

38. This turns upon the poles of the globe, and may be called a *proper* or a *moveable meridian*. It is graduated each way to 90 degrees from the equator to either pole.

39. To this ſemi-circle on the new celeſtial globe is fitted a ſmall thin braſs circle about half an inch diameter, which ſlides from pole to pole; when we conſider the ſun's apparent diurnal motion, we call it an *artificial ſun*.

40. But to the thin ſemi-circle applied to the new terreſtrial globe, is fitted a ſmall thin circle about two inches diameter, that ſlides from pole to pole; which is divided into a few of the points of the mariner's

compaſs, and is called a *terreſtrial* or *viſible horizon.*

The braſs quadrant of altitude

41. Is a thin narrow flexible ſlip of braſs, that will bend to the ſurface of the globe; it has a nut with a fiducial line upon it, which may be readily applied to the diviſions on the ſtrong braſs meridian of either globe; one of its edges is graduated into 90 degrees. Upon the terreſtrial globe its uſe is to ſhew the diſtance of places; and when applied to the celeſtial globe, it ſhews the diſtance between two ſtars. Upon both globes it becomes occaſionally a ſecondary to the horizon; and has other uſes, which will be hereafter ſhewn.

Of the ſeveral circles deſcribed upon the ſurface of each globe.

42. We may imagine as many as we pleaſe upon the ſurface of the earth, and conceive them to be extended to the ſphere of the heavens, marking thereon concentric circles.

43. Great circles paſs through the center, and divide the globe into two equal hemiſpheres: all circles are ſuppoſed to be divided into 360 degrees.

We ſhall begin with the deſcription of the equator, this being the moſt eminent great circle on either globe.

The EQUATOR

44. Is 90 degrees diſtance from the two poles of the globe; and is ſo called, becauſe when the ſun appears to paſs vertically over this circle, the days and nights are of an equal length to all the inhabitants of the earth.

45. The plane of the equator paſſes through the middle of the globe at right angles to the polar-axis.

On our new globes it is graduated into 360 degrees; upon the terreſtrial globe the numbers increaſe from the meridian of London weſtward, and proceed quite round to 360.

46. They are alſo numbered from the ſame meridian eaſtward by an upper row of figures, for the eaſe of thoſe who uſe

the Engliſh tables of the latitude and longitude of places.

47. On our new celeſtial globes the equatorial degrees are numbered from the firſt point of aries eaſtward to 360 degrees.

48. Cloſe under the degrees, on either globe, is graduated a circle of hours and minutes.

49. On the celeſtial globe the hours increaſe eaſtward from aries to XII at libra, where they begin again in the ſame direction and proceed to XII at aries.

50. But the horary numbers under the equator of the terreſtrial globe increaſe by twice twelve hours weſtwards, from the meridian of London to the ſame again.

51. In every poſition of the globe, except that of a parallel-ſphere, the plane of the equator cuts the eaſtern and weſtern points of the broad paper-circle, when conſidered either as an horizon, the ecliptic, or circle of illumination.

And as the globe is turned about, it always keeps to one point of the ſtrong braſs circle, in which, as hath been obſerved, the degrees are numbered both ways from the equator, that the diſtance of latitude north or ſouth of any point on the ſurface of the globe may be more eaſily computed. Whence ariſes the following

PROBLEM II.

To find the latitude of a place.

52. Bring the place to the graduated ſide of the ſtrong braſs meridian, the degree it then cuts ſhews its diſtance from the equator, which on the terreſtrial globe is called *latitude*.

Thus London has 51 deg. 32 min. of north latitude; Conſtantinople 41 deg. of north latitude; Quebec, in Canada, 46 deg. 55 min. of north latitude; and the Cape of Good Hope 34 deg. ſouth latitude.

PROBLEM III.

To find all thoſe places which have the ſame latitude with any given place.

53. Suppoſe the given place London; turn the globe round, and all thoſe places which

paſs under the ſame point of the ſtrong braſs meridian, are in the ſame latitude.

PROBLEM IV.

To find the difference of latitude between any two places.

54. Suppoſe London and Rome, find the latitude of each place by problem ii. art. 52. Their difference is the anſwer.

PROBLEM V.

To find the declination of the ſun or any ſtar.

55. Firſt, On either globe for the *ſun's declination* find his place in the ecliptic by problem i. art. 18. Then bring that point of the ecliptic line upon the globe under the graduated ſide of the ſtrong braſs meridian, and the degree which it cuts is the *ſun's declination* for that day. Or,

Upon the terreſtrial globe, that parallel which paſſes through the point of the ecliptic anſwering to the day of the month, will ſhew the *ſun's declination*, counting the number of parallels from the equator. Alſo,

On the celeſtial globe, ſeek the day of the month cloſe under the ecliptic line itſelf, againſt which is the ſun's place, bring that point under the graduated ſide of the ſtrong braſs meridian, and the degree that ſtands over it is the *ſun's declination* for that day. Thus on the 20th of May the ſun's declination will be about 23 deg. 10 min. and upon the 23d of Auguſt it will be 11 deg. 13 min.

For the declination of any ſtar.

Secondly, Bring the ſtar to the graduated ſide of the ſtrong braſs meridian on the celeſtial globe, and the degree it ſtands under is its diſtance from the equator, and this diſtance is called the *ſtar's declination*, which may be either north or ſouth, according to the ſide of the equator on which the ſtar is ſituated.

Thus the declination of the ſtar Arcturus, marked α in the conſtellation Bootes, has about 20 deg. 30 min. north declination, and that of Syrius in Canis major, or the

dog-ſtar,

dog-ſtar, marked α, is about 16 deg. 30 min. ſouth declination.

56. Hence we ſee that the latitude of places on the earth, and the declination of the ſun and ſtars, &c. in the heavens, have but one idea, the meaning of which is no more than their diſtance (either of places on the terreſtrial, or of the luminaries in the celeſtial ſpheres) from the equator.

57. The declination of a fixed ſtar always continues the ſame, but that of the ſun, moon, and planets, vary.

58. Thoſe ſtars, whoſe declinations are equal to the latitude of any place upon the earth, are called *correſpondents* to that place; and paſs once in every 24 hours vertically to the inhabitants of ſuch latitude: that is, thoſe ſtars appear in their zenith, or are directly over their heads. Hence the following

PROBLEM VI.

To find what ſtars paſs over or nearly over the zenith of any place.

59. Find the latitude of the place by prob. ii. art. 52. upon the terreſtrial globe,

which is the diſtance of that place from the equator; then turning the celeſtial globe, all thoſe ſtars which paſs under the ſtrong braſs meridian at the ſame diſtance from the equator, will paſs directly over the heads of thoſe inhabitants, and therefore become celeſtial correſpondents to all thoſe who live under the ſame parallel of latitude.

Thus the ſtar marked γ of the ſecond magnitude in the head of the dragon is 51 deg. 32 min. diſtant from the celeſtial equator, ſo alſo is London at the ſame diſtance from the terreſtrial equator: therefore the declination of this ſtar is equal to the latitude of London, and conſequently it becomes our celeſtial correſpondent.

The ſtar marked α of the firſt magnitude in Perſeus's ſide, called Algenib, paſſes over the zenith of thoſe inhabitants in France who live 14 min. of one degree ſouth of Paris; it alſo paſſes nearly over the zenith of St. George's Bay in Newfoundland.

Celeſtial and terreſtrial meridians

60. Are great circles drawn upon the globes from one pole to the other, and

croſſing the equator at right angles. Upon our new terreſtrial globe there are twenty-four of theſe meridians, which are alſo hour-circles, being 15 degrees from each other. Thus 15 degrees on the equator is equal to one hour, and each ſingle degree equal to four minutes of time. Only four meridians are drawn upon the ſurface of the celeſtial globe.

61. There are no places on the ſurface of the earth, or ſpaces in the apparent ſphere of the heavens, through which meridians may not be conceived to paſs; conſequently all points on the terreſtrial or in the celeſtial ſpheres have their meridians.

62. This variety of meridians on the globes is ſupplied by the thin braſs ſemi-circle, which being moveable about the poles, may be ſet to every individual point of the equator. Whence we call it a moveable meridian, art. 38.

63. All thoſe great circles, that are drawn from pole to pole, are the meridians of thoſe places through which they paſs.

64. One of theſe meridians on our new terreſtrial globe paſſes through London, and is called *a firſt meridian*; becauſe from that point where it croſſes the equator, the degrees

of longitude, and the hours and minutes of time, begin.

Some geographers make their firſt meridian paſs through the iſle of Fer or Ferro.

PROBLEM VII.

To find the longitude of a place.

65. The longitude of any place is that point or degree upon the equator which is croſſed by the meridian of that place, reckoned from a firſt meridian.

Bring the graduated edge of the moveable meridian to the place, and that degree on the equator which is cut by the ſame edge, is its longitude from London, in degrees, and minutes, or that hour and minute is its longitude expreſſed in time.

Or if we bring the place to the graduated ſide of the ſtrong braſs meridian, that will cut the equator in the longitude as before.

Thus Boſton in New England is about 70½ degrees weſt of London; Cape Comorin in the Eaſt Indies 282°. weſt of London, or the longitude of the firſt place expreſſed in time is 4 h. 42 min. of the ſecond 18 h. 48 min.

66. The method of reckoning longitude always weſtward from the firſt meridian is moſt natural, becauſe it is agreeable to the real motion of the earth;

67. But the common method is to reckon it half round the globe eaſtward, and the other half weſtward from the firſt meridian, ending either way at 180 degrees.

Thus Cape Comorin is 78 degrees eaſt of London.

Note, The numbers neareſt the equator increaſe weſtward from the meridian of London quite round the globe to 360, over which another ſet of numbers is engraved which increaſe the contrary way, by which means the longitude may be reckoned upon the equator either eaſt or weſt.

68. It is mid-day or noon to all places in the ſame meridian at the ſame time.

Thus London, Oran, Cape Coaſt-caſtle in the Mediterranean, and Mundfort on the Gold-coaſt, have their noon nearly at the ſame time; Boſton in New England about 4 h. 42 min. later; and Cape Comorin 18 h. 48 min. later.

69. The difference of longitude of any two places is the quantity of an angle at the pole made by the meridians of thoſe places; which angle is meaſured upon the equator.

To expreſs this angle upon the globe

70. Bring the graduated edge of the moveable meridian to one of the places, and the other place under the graduated ſide of the ſtrong braſs circle: they then contain the required angle; the meaſure or quantity of which is the number of degrees counted on the equator between theſe two braſs meridians.

PROBLEM VIII.

To find what places have mid-day or the ſun upon their meridian, at any given hour of the day in any place propoſed.

71. Firſt, Let the hour propoſed be X o'clock in the morning at London.

As the real diurnal motion of the earth, here repreſented by the terreſtrial globe, is from weſt to eaſt,

72. All places to the eaſtward of any particular meridian muſt neceſſarily paſs by the ſun, before the meridian of any other place to the weſtward of that particular meridian can arrive at it.

73. And therefore as the firſt meridian on our new terreſtrial globe paſſes through London, if the propoſed place be London, as in this caſe, bring the given hour to the eaſt of London if it be in the morning, but to the weſt of London if it be in the afternoon, to the graduated ſide of the ſtrong braſs meridian; and all thoſe places which lie directly under it, have noon or the ſun upon their meridian when it is X o'clock at London.

Thus having brought the Xth hour on the equator to the eaſtward of London under the divided ſide of the ſtrong braſs meridian, it will be found to paſs over the eaſtern ſide of Lapland, and the eaſtern extremity of the gulf of Finland, Peterſburgh in Ruſſia, to croſs a part of Moldavia and the Black Sea, thence it paſſes over a part of Turky, and goes between the iſlands of Candia and Cyprus in the Mediterranean, thence over the middle of Egypt through the eaſtern ſide of Africa, and acroſs the bay of Lorenzo; all which places have the ſun on their meridian when it is X o'clock in the morning at London.

74. Secondly, Let the hour propoſed be IV o'clock in the afternoon at Port-Royal in Jamaica.

Bring Port-Royal in Jamaica to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to that XII which is moſt elevated; then turn the globe from weſt to eaſt, until the horary index points to IV o'clock, and the ſtrong braſs meridian will paſs over the weſtern ſide of the iſle Paſares in the Pacific ocean; and the eaſtern ſide of the iſle la Meſæ, thence it croſſes the equator, and paſſes nearly over the iſlands Mendoca and Dominica, which places have the ſun on their meridian when it is IV o'clock in the afternoon at Port-Royal in Jamaica.

75. Thirdly, Let the propoſed hour be 30 min. paſt V o'clock in the morning at Cape Paſaro in the iſland of Sicily.

Bring Cape Paſaro to the graduated ſide of the ſtrong braſs meridian, ſet the horary index to that XII which is moſt elevated, and turn the globe weſtward, becauſe the propoſed time is in the morning, till the horary index points to 5 h. 30 min. and you'll find the ſtrong braſs meridian to paſs over the middle of Siberia, Chineſe Tartary, the kingdom of China, Kanton in China, the middle of the iſland of Borneo, &c. at all which places it is noon, (they having the ſun upon their meridian at the ſame time) when it is half an hour paſt V o'clock in the morning at Cape Paſaro in Sicily.

PROBLEM IX.

To find what hour it is at any place propoſed when it is noon at any given place.

76. Bring the propoſed place under the graduated ſide of the ſtrong braſs meridian,

and ſet the horary index to XII (if the given place be London, the graduated ſide of the ſtrong braſs meridian is the horary index) then turning the globe, bring the given place to the meridian and the hour required will be ſhewn by the horary index upon the equator. If the propoſed place be to the eaſtward of the given place, the anſwer will be after noon, but if to the weſtward of it, the anſwer is before noon.

Thus when it is noon at London, it is 49 minutes paſt XII at Rome, and 32 minutes paſt VII in the evening at Kanton in China, and alſo 15 minutes paſt VII o'clock in the morning at Quebec in Canada, and this at one and the ſame inſtant of time.

Problem X.

At any given time of the day in the place where you are, to find the hour at any other place propoſed.

77. Bring the propoſed place under the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to the given time; then

turn the globe till the place where you are is under the braſs meridian, and the horary index will point to the hour and minute required.

Thus ſuppoſe we are at London at IX o'clock in the morning, what time of the day is it then at Kanton in China? anſwer 31 minutes paſt IV in the afternoon.

Alſo, when it is IX in the evening at London, it is about 15 minutes paſt IV o'clock in the afternoon at Quebec in Canada.

PROBLEM XI.

The latitude and longitude of any place being known; to find that place upon the globe, or if it be not inſerted, to find its place and fix the center of the artificial horizon thereon.

78. The latitude of Smyrna in Aſia is 38 deg. 28 min. north, its longitude 27 deg. 30 min. eaſt of London.

Bring 27 deg. 30 min. on the equator eaſtward of our firſt meridian to the graduated face of the ſtrong braſs circle, and under 38 deg. 28 min. on the north ſide of the equator you will find Smyrna.

The latitude of Cape Lorenzo in Peru is 1 deg. 2 min. ſouth, and longitude 80 deg. 17 min. weſt of London: this place is not inſerted upon the globe. Therefore bring the graduated edge of the moveable meridian to 80 deg. 17 min. counted weſtward on the equator, and ſlide the diameter of the artificial horizon to 1 deg. 2 min. ſouth; and its center will be correctly placed on that point of the globe where the Cape of Lorenzo ought to have been placed.

The four laſt problems depend entirely on the knowledge of the longitude and difference of longitude of places.

The ecliptic

79. Is that graduated circle which croſſes the equator in an angle of about 23½ degrees; and this angle is called the obliquity of the ecliptic.

80. This circle is divided into 12 equal parts, each of which contains 30 degrees; the beginning of each 12th part is marked

with the uſual characters ♈, ♉, ♊, ♋, ♌, ♍, ♎, ♏, ♐, ♑, ♒, ♓, by which the twelve ſigns are repreſented upon the terreſtrial globe. But upon our celeſtial globe, juſt under the ecliptic, the months, and days of each month, are graduated, for the ready fixing the artificial ſun upon its place in the ecliptic.

81. The ſun's apparent place is always in this circle; he advances therein every day about 59 min. 8 ſec. of one degree, and ſeems to paſs through it in a tropical year.

82. Thoſe two points, where the ecliptic croſſes the equator, are called *equinoctial points*, and are marked with theſe characters ♈ and ♎ at the beginning of Aries and Libra.

83. The firſt of theſe is called the *vernal*, the ſecond the *autumnal equinox*.

84. The beginning of cancer and capricorn are marked with the characters ♋ and ♑, which two points are called the ſolſtices; the firſt is the ſummer ſolſtice, the ſecond that of the winter, to all inhabitants upon the north ſide of the equator; but directly contrary to thoſe on the ſouth ſide of it.

Although the ecliptic does not properly belong to the earth, yet we have placed it upon our terreſtrial globe according to ancient cuſtom; it being uſeful in ſome particular caſes; it is chiefly to be regarded upon the celeſtial globe.

85. The longitude of the ſtars and planets is reckoned upon the ecliptic; the numbers beginning at the firſt point of aries ♈, where the ecliptic croſſes the equator and increaſing according to the order of the ſigns.

86. The latitude of the ſtars and planets is determined by their diſtance from the ecliptic upon a great circle paſſing through its poles, and croſſing it at right angles.

87. Twenty-four of theſe circular lines, which croſs the ecliptic at right angles, being fifteen degrees from each other, are drawn upon the ſurface of our celeſtial globe; which being produced both ways, thoſe on one ſide meet in a point on the northern polar-circle, and thoſe on the other meet in a point on the ſouthern polar-circle.

88. The points determined by the meeting of theſe circles are called the *poles* of the ecliptic, one *north*, the other *ſouth*.

89. The longitude of the ſtars hath been obſerved to increaſe about a degree in 72 years.

The celeſtial ſigns and conſtellations

90. On the ſurface of the celeſtial globe are repreſented by a variety of human and other figures, to which the ſtars that are either in or near them, are referred.

91. The ſeveral ſyſtems of ſtars, which are applied to thoſe images, are called *conſtellations.* Twelve of theſe are repreſented on the ecliptic circle, and extend both northward and ſouthward from it. So many of thoſe ſtars which fall within the limits of 8 degrees on both ſides of the ecliptic circle, together with ſuch parts of their images as are contained within the aforeſaid bounds, conſtitute a kind of broad hoop, belt, or girdle, which is called the *zodiac.*

92. The names and the reſpective characters of the twelve ſigns of the ecliptic may be learned by inſpection on the ſurface of the broad paper circle; and the conſtellations from the globe itſelf.

93. The zodiac is repreſented by eight circles parallel to the ecliptic, on each ſide thereof; theſe circles are one degree diſtant from each other, ſo that the whole breadth of the zodiac is 16 degrees.

94. Amongſt theſe parallels, the latitude of the planets is reckoned; and in their apparent motion they never exceed the limits of the zodiac.

95. On each ſide of the zodiac, other conſtellations are diſtinguiſhed; thoſe on the north ſide are called northern, and thoſe on the ſouth ſide of it, ſouthern conſtellations.

96. All the ſtars which compoſe theſe conſtellations, are ſuppoſed to increaſe their longitude continually; upon which ſuppoſition the whole ſtarry firmament has a ſlow motion from weſt to eaſt; inſomuch that the firſt ſtar in the conſtellation of aries, which appeared in the vernal interſection of the equator and ecliptic in the time of *Meton* the Athenian, upwards of 1900 years ago, is now removed about 30 degrees from it.

97. From the different magnitudes of the ſtars, ſome appear to be greater than others, or nearer to us: on our celeſtial

globe, they are diſtinguiſhed into ſeven different magnitudes.

General phænomena ariſing from the earth's diurnal motion.

98. The daily rotation of the earth about its axis is one of the moſt eſſential points, which a beginner ought to have in view; for every particular meridian thereon is ſucceſſively turned towards every point in the heavens, and as it were deſcribes circles in the celeſtial ſphere, perpendicular to the axis of the earth, and parallel to each other; by which means the fixed ſtars ſeem to have an apparent diurnal motion.

99. Except thoſe two points in the ſtarry firmament, into which the earth's axis, ſuppoſed to be ſo far extended, would fall; theſe two points are called the *celeſtial poles*, which correſpond with our terreſtrial north and ſouth poles.

100. We have contrived our new globes ſo that the real diurnal motion of the earth and the apparent diurnal motion of the heavens are repreſented by them, art. 5. 6.

and thence all problems ſolved as readily in *ſouth* as in *north* latitudes, and in places on or near the equator: by which means we are enabled to ſhew, how the viciſſitudes of days and nights, their various alterations in length, the duration of the twilight, &c. are really made by the earth's daily motion, upon the principles of the Pythagorean and Copernican ſyſtems.

101. In fig. 3. Æ N Q S Æ repreſent s the apparent concave ſphere of the fixed ſtars, æ n q s æ the globe of the earth, whoſe axis n s is ſuppoſed to be extended to N S, in the ſphere of the fixed ſtars; all the ſtars ſeem to revolve upon theſe two points as poles.

102. If the plane of the earth's equator æ z q c æ, is conceived to be extended to the ſtarry firmament, it will point out the celeſtial equator Æ ♎ Q ♈ Æ.

103. N repreſents the celeſtial, and n the terreſtrial north pole, S and s the ſouth pole.

Parallels of latitude, declination, tropics and polar-circles.

104. Fig. 3. That circle which any ſtar ſeems to deſcribe in twenty-four hours, is

called its *parallel:* thus, ſuppoſe a right line drawn from C the center of the earth, through any point d of its ſurface, and extended to D in the ſtarry firmament, by means of the earth's daily rotative motion, the extremity D of the line C D will deſcribe the celeſtial parallel G x D x G, correſponding to the terreſtrial parallel g d, of the point d. If D C be ſuppoſed to be extended to H, the oppoſite ſide of the ſtarry firmament, it will deſcribe another parallel equal to the former.

105. Thoſe circular lines upon the terreſtrial globe, which are deſcribed from the poles, on either ſide of the equator, are parallel to it, and are called *parallels of latitude*, but on the celeſtial globe they are called *parallels of declination.*

106. There are four principal leſſer circles parallel to the equator, which divide the globe into five unequal parts called *zones*; theſe are the two tropics, and the two polar-circles.

107. We have already ſhewn, that the diſtance of any parallel from the equator, meaſured in the arch of a great circle on the

terreſtrial ſphere, is its latitude; and on the celeſtial ſphere, its declination, art. 56.

108. If the ſun, moon, a fixed ſtar, or planet, is ſituated in any parallel between the equator Æ Q, fig. 3. and the north pole N, it is ſaid to have north declination, but if towards the ſouth pole S, ſouth declination.

109. Thus the two parallels G D, and H I, have the ſame declination: becauſe they are equally diſtant from Æ Q the equator; the firſt hath north, the laſt ſouth declination.

110. Hence we muſt obſerve, that a celeſtial parallel G X D, and its correſpondent g x d upon the earth, are two parallel-circles, being ſimilar elements of a cone whoſe axis is that of the earth, and apex C the center of the earth. Therefore the plane of a terreſtrial parallel cannot be the ſame with its correſpondent celeſtial parallel; only the plane of the celeſtial equator Æ ♎ Q ♈ Æ, is the ſame with that of the terreſtrial equator æ z q, becauſe theſe two planes are produced by the ſame radius C Q perpendicular to the axis N S on which the earth or the heavens are ſuppoſed to turn.

111. If by the earth's daily rotative motion, a ſtar D paſſes over the zenith d of any inhabitant of the earth, that ſtar is in the celeſtial parallel, which correſponds to the terreſtrial parallel of the obſerver; for the diſtance of the celeſtial parallel G D contains the ſame number of degrees from Æ Q the celeſtial equator, as that of the inhabitant's parallel g d does from æ q the terreſtrial equator.

112. Therefore the meaſure of the arch of any inhabitant's diſtance from the terreſtrial equator, which is called the *latitude* of the place, is ſimilar and equal in the number of degrees, to that fixed ſtar's *declination*, which paſſes over his zenith.

113. If the inhabitant changes his ſituation either north or ſouth, the different declinations of thoſe ſtars which paſs over his zenith, at the ſeveral places of his removal, will ſhew his advance to, or regreſs from the equator.

114. Whence any place upon the earth may be repreſented by its correſponding zenith point, in the apparent concavity of the ſtarry ſphere; as ſhall be hereafter ſhewn.

115. Upon our new terreſtrial globe, there are twenty-three parallels drawn at the

diſtance of one degree from each other, on both ſides the equator; which, with two other parallels at 23½ degrees diſtance, include the ecliptic circle; theſe two are called the *tropics.* That on the north ſide of the equator is called the tropic of *cancer:* and the other, which is on the ſouth ſide of it, the tropic of *capricorn.*

116. The ſpace between theſe two tropics, which contains about 47 degrees, was called by the ancients, the *torrid zone.*

117. The two *polar-circles* are placed at the ſame diſtance from the poles, as the two tropics are from the equator.

One of theſe is called the *northern,* the other the *ſouthern polar-circle.*

118. Theſe include 23½ degrees on each ſide of their reſpective poles, and conſequently contain 47 degrees, equal to the number of degrees included between the tropics.

119. The ſpace contained within the northern polar-circle, was by the ancients called the *north frigid zone,* and that within the ſouthern polar-circle the *ſouth frigid zone.*

120. The ſpaces between either polar-circle, and its neareſt tropic, which contain

about 43 degrees, were by the ancients called the *two temperate zones.*

121. Wherever any parallel paſſes through two places on the terreſtrial globe, thoſe places have the ſame latitude.

122. Alſo all thoſe ſtars which are in the ſame parallel upon the celeſtial globe, have the ſame declination.

123. And as the ecliptic is inclined to the equator in an angle of 23½ degrees, and is included between the two tropics, every parallel in the torrid zone muſt neceſſarily croſs the ecliptic in two places; which two points ſhew the ſun's place, when he is vertical to the inhabitants of that parallel; and the days of the month upon the broad paper-circle anſwering to thoſe points of the ecliptic, are the days on which the ſun paſſes directly over their heads at noon, and are called their two midſummer days: whence the inhabitants of the torrid zone have two ſummers and two winters every year.

124. Hence as the earth's progreſſive, or rather apparent annual motion, ſeems to be in the celeſtial ecliptic, the ſun's declination is thereby changed gradually every day.

Therefore on our new terreſtrial globe, as mentioned in art. 115. we have drawn parallels through the whole ſpace of the torrid zone, and the two ſpaces within the polar-circles, to give a general and clear idea of the ſun's apparent paſſage from one tropic to the other.

The colures

125. Are circular lines drawn on the celeſtial globe from pole to pole, (as meridians are upon the terreſtrial globe) croſſing the equator at right angles.

126. There are four colures, which form two great circles of the ſphere.

127. That colure or celeſtial meridian, which goes through the firſt point of aries ♈, and that which paſſes through the firſt point of libra ♎, making together one great circle, is repreſented by the circle B ♈ K ♎ in fig. 3. and is called the *equinoctial colure.* The points marked ♈ and ♎ are called the *equinoxes,* or equinoctial points.

128. The two celeſtial meridians repreſented by the circle N Æ S Q N, paſſing through the ſolſtitial points (marked ♋ and

♑) of cancer and capricorn, are called the *ſolſtitial colures.*

129. Theſe colures cut each other at right angles in the poles of the world, and divide the celeſtial equator, ecliptic, and zodiac into four equal parts.

130. The equinoctial colure only paſſes through the poles of the world at N and S. But,

131. The ſolſtitial colure paſſes through the poles of the world at N and S, and alſo through the poles of the ecliptic at B and K. Fig. 3.

132. Whence it happens in every daily rotation of the earth about its axis, that the ſolſtitial and equinoctial colures are twice blended with every meridian upon the ſurface of the earth: conſequently, each pole of the ecliptic appears to paſs, once every day, over all the meridians of the terreſtrial ſphere.

133. All thoſe circular lines that are or may be ſuppoſed drawn on the celeſtial globe, which paſs through the poles, cutting the equator at right angles, are called *circles of declination*; becauſe the declination of thoſe points or ſtars through which they

paſs, or the diſtance of thoſe ſtars from the equator, is meaſured upon theſe circles: and this is done by bringing the divided edge of the moveable meridian to any ſtar.

134. Hence the thin braſs ſemi-circle, art. 38. which we call the moveable meridian, is alſo a moveable circle of declination.

Arctic and antarctic circles, or circles of perpetual apparition and occultation.

135. The largeſt parallel of latitude on the terreſtrial globe, as well as the largeſt circle of declination on the celeſtial, that appears entire above the horizon of any place in north latitude, is called by the ancients the *arctic circle* or circle of perpetual apparition.

136. Between the arctic circle and the north pole in the celeſtial ſphere, are contained all thoſe ſtars which never ſet at that place, and ſeem to us, by the rotative motion of the earth, to be perpetually carried round above our horizon in circles parallel to the equator.

137. The largeſt parallel of latitude on the terreſtrial, and the largeſt parallel of declination on the celeſtial globe, which is entirely hid below the horizon of any place, is by the ancients called *the antarctic circle*, or circle of perpetual occultation.

138. This circle includes all the ſtars which never riſe in that place to an inhabitant of the northern hemiſphere, but are perpetually below the horizon.

139. Hence all arctic circles touch their horizons in the north point, and all antarctic circles touch their horizons in the ſouth point; which point, in the terreſtrial and celeſtial ſpheres, is the interſection of the meridian and horizon.

140. If the elevation of the pole be 45 degrees, the moſt elevated part, either of the arctic or antarctic circle, will be in the zenith of the place.

141. If the pole's elevation be leſs than 45 degrees, the zenith point of thoſe places will fall without its arctic or antarctic circle. If greater, it will fall within.

142. Therefore the nearer any place is to the equator, the leſſer will its arctic and antarctic circles be; and on the contrary,

the farther any place is from the equator, the greater they are. So that,

143. At the poles, the equator may be conſidered as both arctic and antarctic circle, becauſe its plane is coincident with that of the horizon.

144. But at the equator (that is, in a right ſphere) there is neither arctic nor antarctic circle.

145. They who live under the northern polar-circle, have the tropic of cancer for their arctic, and that of capricorn for their antarctic circle.

146. And they who live on either tropic, have one of the polar-circles for their arctic, and the other for their antarctic circle.

147. Hence whether theſe circles fall within or without the tropics, their diſtance from the zenith of any place is ever equal to the difference between the pole's elevation, and that of the equator above the horizon of that place.

148. From what has been ſaid it is plain, there may be as many arctic and antarctic circles, as there are individual points upon any one meridian, between the north and ſouth poles of the earth.

149. Many authors have miſtaken theſe mutable circles, and have given their names to the immutable polar-circles, which laſt are arctic and antarctic circles, in one particular caſe only, as has been ſhewn.

The cauſe of the daily change in the declination of the ſun

150. Ariſes from the earth's annual motion, in the ecliptic, the inclination of her axis, and its always moving parallel to itſelf.

151. Imagine the plane of the earth's orbit extended as far as the fixed ſtars, it will there mark out the circle ♋, ♎, ♑, ♈, ♋, which we call the celeſtial ecliptic; ſee fig. 3.

152. From this compariſon of the earth's orbit with the celeſtial ecliptic, is derived the ancient rule to find the ſun's place, if we firſt find the earth's place, either by obſervation or calculation; ſix ſigns added to or ſubſtracted from it gives the ſun's true place in the ecliptic. Conſequently it is the ſame thing, when we conſider the daily motion

of the earth about her equatorial axis, repreſented by the terreſtrial globe, whether we ſuppoſe the earth, or the ſun, to have an annual motion.

153. It is alſo the ſame thing in the uſe of the celeſtial globe, whether we ſuppoſe the earth to turn upon her equatorial axis, or the ſtarry ſphere to revolve upon the extremities of the ſame axis extended to the heavens: the reſult in either caſe will be the ſame, provided we conceive ourſelves at the center of the globe.

154. Hence we ſhall ſuppoſe the ſun's apparent annual motion to be in the plane of the celeſtial ecliptic, and in his paſſage through it, deſcribing by a ray connecting the centers of the earth and ſun, a different circle of declination, parallel to the equator every day. Whereby all thoſe people who inhabit any of thoſe places on the earth which are ſituated between the terreſtrial tropic of cancer repreſented in fig. 3. by ♋, e, and the terreſtrial tropic of capricorn repreſented by h, ♑, have the ſun at the time he is deſcribing their parallel in their zenith; or directly vertical, or over their heads, which happens twice every year.

155. Whence the inhabitants of thoſe places, as well as mariners who paſs between the tropics, have a correſponding zenith-point, where their latitude is equal to the ſun's parallel of declination, from the ſun by day, and from the ſtars by night.

156. Hence it is eaſily conceived, that if the planes of the equator and ecliptic were united in one continued plane, a central ſolar ray connecting the centers of the earth and ſun, would by the earth's diurnal motion deſcribe the equator every day; but, as we have before obſerved, the ſun does apparently deſcribe a different parallel every day: wherefore the ecliptic and equator are inclined to each other in an angle confirmed by obſervation of about 23 deg. 29 min.

157. Let the ſun's apparent annual motion be repreſented by the circle ♋, ♎, ♈, ♋, fig. 3. which biſects the celeſtial equator Æ ♎ Q ♈ Æ, in the points ♎ and ♈; the firſt of theſe is called the autumnal, the ſecond the vernal equinoctial point.

158. When the ſun is in ♎, he appears to deſcribe the equator, at which time he has no declination; and as he proceeds

gradually from ♎ towards ♑, his ſouthern declination continually increaſes, and he deſcribes leſs and leſs parallels, till he appears in ♑, and then deſcribes the tropic of capricorn; being then at his greateſt ſouthern declination, and at his greateſt diſtance from the equator ſoutherly, and alſo in the winter-ſolſtice.

159. It paſſing from ♑ to ♈, his declination decreaſes, and the parallels he deſcribes are greater and greater, until he comes to aries or the vernal equinox, and again has no declination, deſcribing the equator as before.

160. As he advances from thence towards ♋, the declination increaſes, and the parallels deſcribed are leſs and leſs, until he arrives at ♋ or the ſummer-ſolſtice; being then at his greateſt north declination, deſcribing the tropic of cancer.

161. Thence proceeding forwards towards ♎, the declination continually decreaſes, and the parallels deſcribed increaſe till the ſun's arrival at the next ſucceeding autumnal equinox; where he again deſcribes the equator, having no declination; and compleats the length of a mean ſolar

tropical year, containing 365 d. 5 h. 49 min.

162. What we have ſaid with reſpect to ſummer and winter-ſolſtices, is to be underſtood with relation to thoſe places which lie between the equator and the north pole; but to the places between the equator and ſouth pole the contrary happens.

163. The two equinoxes are the ſame to all the inhabitants of the earth.

164. We have been thus particular in our deſcription of the ſun's apparent annual motion, for the uſe of beginners; and we hope this conſideration will plead in our behalf, if we ſhould appear tedious or trifling to thoſe who are maſters of the ſubject.

165. But what has been ſaid, might yet be more clearly illuſtrated by an orrery or a tellarium, which ſhews the annual and diurnal motions of the earth and paralleliſm of its axis, &c. which by the different poſitions of the earth's axis, with reſpect to her enlightened diſc, will appear to the eye as it is really underſtood by aſtronomers, and then we may with more propriety repair to the uſe of the globe itſelf.

To

To ſupply the want of a tellarium,

Deſcribe a circle with chalk upon the floor, as large as the room will admit of, that the globe may be moved round upon it: divide this circle into twelve parts, and mark them with the characters of the twelve ſigns, as they are engraved upon the broad paper circle; placing ♋ at the north, ♑ at the ſouth, ♈ in the eaſt, and ♎ in the weſt: the mariners compaſs under the globe will direct the ſituation of theſe points, if the variation of the magnetic needle be attended to.

Note, At London the variation is between 19 and 20 degrees from the north weſtward.

Elevate the north pole of the globe that 66½ degrees on the ſtrong braſs meridian may coincide with the ſurface of the broad paper circle, and this circle will then repreſent the plane of the ecliptic, as mentioned in article 24.

Set a ſmall table or a ſtool over the center of the chalked circle to repreſent the ſun, and place the terreſtrial globe upon its circumference over the point marked ♑, with the north pole facing the imaginary ſun, and the north end of the needle pointing to the variation: this is the poſition of the earth with reſpect to the ſun at the time of the ſummer-ſolſtice about the 21ſt of June: and the earth's axis, by this rectification of the globe, is inclined to the plane of the large chalked circle, as well as to the plane of the broad paper circle, in an angle of 23½ degrees; a line or ſtring paſſing from the center of the imaginary ſun to that of the globe, will repreſent a central ſolar ray connecting the centers of the earth and ſun: this ray will fall upon the firſt point of cancer, and deſcribe that circle, ſhewing it to be the ſun's place upon the terreſtrial ecliptic, which is the ſame as if the ſun's place, by extending the ſtring, was referred to the oppoſite ſide of the chalked circle, here repreſenting the earth's path in the heavens.

If we conceive a plane to paſs through the axis of the globe, it will alſo paſs through the ſun's center, and the points of cancer and capricorn in the terreſtrial and celeſtial ecliptic; the central ſolar ray in this poſition of the earth is alſo in that plane; this can never happen but at the times of the ſolſtice.

If another plane be conceived to paſs through the center of the globe at right angles to the central ſolar ray, it will divide the globe into two hemiſpheres; that next the center of the chalked circle will repreſent the earth's illuminated diſk, the contrary ſide of the ſame plane will at the ſame time ſhew the obſcure hemiſphere.

The intelligent reader for the uſe of his pupils, may realize this ſecond plane by cutting away a ſemi-circle from a ſheet of card paſte-board, with a radius of about 1½ tenths of an inch greater than that of the globe itſelf; if this plane be applied to 66½ degrees upon the ſtrong braſs meridian, it will be in the pole of the ecliptic; and in every ſituation of the globe round the circumference of the chalked circle, it will afford a lively and laſting idea of the annual and diurnal motion of the earth, of the various phænomena ariſing from the parallelïſm of the earth's axis, and in particular the daily change of the ſun's declination, and the parallels thereby deſcribed.

Let the globe be removed from ♑ to ♒, and the needle pointing to the variation as before will preſerve the paralleliſm of the earth's axis; then it will be plain, the ſtring or central ſolar ray will fall upon the firſt point of leo, ſix ſigns diſtant from, but oppoſite to the ſign ♒ upon which the globe ſtands: the central ſolar ray will now deſcribe the 20th parallel of north declination, which will be about the 23d of July.

If the globe be moved in this manner from point to point round the circumference of the chalked circle, and care be taken at every removal that the north end of the magnetic needle, when ſettled, points to the degree of the variation, the north pole of the globe will be obſerved to recede from the line connecting the centers of the earth and ſun, until the globe is placed upon the point cancer: after which, it will at every removal tend more and more towards the ſaid line, till it comes to capricorn again.

PROBLEM XII.

To rectify either globe to the latitude and horizon of any place.

166. If the place be in north latitude, raiſe the north pole, if in ſouth latitude, raiſe the ſouth pole, until the degree of the given latitude, reckoned on the ſtrong braſs meridian under the elevated pole, cuts the plane of the broad paper circle; then this circle will repreſent the horizon of that place.

To rectify for the ſun's place.

167. After the former rectification bring the degrees of the ſun's place in the ecliptic line upon the globe to the ſtrong braſs meridian, and ſet the horary index to that XIIth hour upon the equator which is moſt elevated.

168. Or, if the ſun's place is to be retained, to anſwer various concluſions, bring the graduated edge of the moveable meridian to the degree of the ſun's

place in the ecliptic, upon the celeſtial globe, and ſlide the wire which croſſes the center of the artificial ſun thereto, then bring its center which is the interſection of the aforeſaid wire, and graduated edge of the moveable meridian, under the ſtrong braſs meridian as before, and ſet the horary index to that XII on the equator which is moſt elevated.

To rectify for the zenith of any place.

169. After the firſt rectification ſcrew the nut of the quadrant of altitude ſo many degrees from the equator reckoned on the ſtrong braſs meridian towards the elevated pole, as that pole is raiſed above the plane of the broad paper circle, and that point will repreſent the zenith of the place.

Thus London having 51½ degrees north latitude, move the globe till the plane of the horizon on the north ſide cuts the ſtrong braſs meridian in that point.

170. If you are doubtful, whether the proper point of the braſs meridian is correctly cut, when ſet by the eye, apply a card

cut in the ſhape of fig. 4. to the place flat upon the broad paper circle, and it will be truly adjuſted.

If, when the globe is in this ſtate, we look on the oppoſite ſide of the globe, the plane of the horizon will cut the ſtrong braſs meridian at 38½ degrees, the complement of the latitude.

PROBLEM XIII.

To find the moon's mean place upon the celeſtial globe, her age and day of the month being known.

172. The moon increaſes her longitude in the ecliptic every day about 13 deg. 10 min. by which means ſhe croſſes the meridian of any place about 50 minutes later than ſhe did the preceding day.

Thus if her place be in the 12th degree of Taurus any day at noon, it will be 25 deg. 10 min. in Taurus on the ſucceeding noon.

173. It is *new moon* when the ſun and moon have the ſame longitude, or are in or near the ſame point of the ecliptic.

174. When they have oppoſite longitudes, or are in oppoſite points of the ecliptic, it is *full moon.*

175. To perform this problem tolerably near the truth, without having recourſe to an ephemeris, which may not always be at hand,

176. Find the day of the new moon next preceding, the given day of the month in any common almanack, the number of days elapſed is the moon's age.

177. The equator on our new celeſtial globe is divided by large dots into 29½ equal parts, each of which is directed by a ſhort dotted line, to a number marked in Roman figures, expreſſing the ſeveral days of the moon's age.

The rule.

178. Elevate the north pole of the celeſtial globe to 90 degrees, and then the equator will be in the plane of the broad paper circle; bring the firſt point of aries, marked ♈ on the globe, to the day of the month on the ſaid broad paper circle, which anſwers to the ſun's place for that day; and

the day of the moon's age will ſtand againſt the ſign and degree of the moon's mean place; to which ſet the artificial moon upon the ecliptic on the globe.

179. But if you are provided with an ephemeris, that will give the moon's latitude and place in the ecliptic; firſt note her place in the ecliptic upon the globe, and then counting ſo many degrees amongſt the parallels in the zodiac, either above or below the ecliptic, as her latitude is north or ſouth upon the given day, and that will be the point which repreſents the true place of the moon for that time, to which apply the artificial moon.

180. Note, The artificial moon is a ſmall thin piece of braſs in form of a creſcent, having two holes a and b, fig. 5. through which a ſmall ſtring of ſilk twiſt is put, that it may ſlip backwards or forwards upon it.

181. To one end c of this ſilk ſtring is tied a ſmall piece of braſs d e c with three holes, at d e c.

The manner of putting it upon the globe is thus: firſt having put the creſcent a b, on the ſtring and the piece of braſs, by paſſing the ſtring through the two holes d, e, the ſtring being as yet left free. The two ends of the ſtring being looſe, paſs the end F round the north pole of the globe, in a grove made for that purpoſe, and tie it into a looſe loop like F g, then put the other end of the ſtring G c round the ſouth pole and tie it faſt to the hole at c, then by pulling the piece d e c upwards, the ſtring may be tightned on any part of the globe, and puſhing it downwards will ſlacken it, that it may be removed to any other place and then tightned again.

PROBLEM XIV.

To repreſent the apparent diurnal motion of the ſun, moon, and ſtars, on the celeſtial globe.

182. Find the ſun's place by problem I. art. 52. and thereto ſet the center of the artificial ſun. Alſo,

183. Find the moon's place by problem xiii. art. 171. and ſet the center of the artificial moon upon it.

Rectify the globe to the latitude, horizon, ſun's place, and zenith, by problem xii. art. 166, 167, and 169.

184. The globe being turned round its axis from eaſt to weſt, will repreſent the apparent motion of the ſun, moon, and ſtars, for that day.

185. When the center of the artificial ſun is in the plane of the horizon on the eaſtern ſide, the horary index ſhews upon the equator the time of *ſun riſing*.

186. All thoſe ſtars which are then in the plane of the horizon on the eaſtern ſide, are at the ſame inſtant of time riſing with the *ſun*, and thoſe on the weſtern ſide of the horizon are then ſetting.

187. And when the center of the artificial moon comes to the horizon on the eaſtern ſide, the horary index will point to the hour and minute of her riſing.

And thoſe ſtars on the eaſt edge of the horizon are then riſing with her, whilſt at the ſame time all thoſe ſtars, cut by the weſtern edge, are ſetting.

188. That degree and minute of the equator which is cut by the plane of the horizon, at the ſame time, that the center of

the artificial ſun, moon, or any ſtar, is alſo cut by the ſaid plane, is the very point of the equator, which riſes with either of them, and is called the ſun, moon, or ſtars *oblique aſcenſion.*

189. As the *ſun* aſcends in the heavens till it culminates, or comes under the graduated ſide of the ſtrong braſs meridian, the horary index will ſucceſſively point to the hours before noon; but when he is under the divided ſide of the braſs meridian, the horary index points at XII o'clock, and that degree and minute on the equator, which is cut by the graduated face of the ſtrong braſs meridian, is called the *ſun's right aſcenſion.*

190. At the ſame time, that degree of the braſs meridian, which is directly over the artificial ſun, is his *declination*, art. 55. for that day.

192. The ſame is to be obſerved of the moon or any ſtar as they aſcend in the heavens, till they culminate or come under the meridian, the horary index conſtantly pointing to the hour of the day or night; their right aſcenſion and declination are alſo ſhewn in the ſame manner as that of the ſun.

193. Whilſt the ſun deſcends from the meridian weſtward, the horary index ſucceſſively ſhews the hours after noon.

194. And when the center of the artificial ſun is in the plane of the horizon on the weſtern ſide, the horary index ſhews the time of *ſun ſetting*; and that point of the equator which is then cut by the plane of the horizon, is the point which ſets with the ſun, and is called his *oblique deſcenſion.*

195. The number of degrees on the equator contained between the points of his oblique aſcenſion, and right aſcenſion, or between the points of his right aſcenſion and oblique deſcenſion, is called his *aſcenſional difference.*

196. Obſerve the ſame with reſpect to the moon or any ſtar: as they deſcend from the meridian weſtward, the horary index will ſucceſſively ſhew the time of their arrival at any given point, their ſetting, oblique deſcenſion and aſcenſional difference in the ſame manner as before deſcribed in relation to the ſun.

197. The riſing, culminating, ſetting, &c. of any planet may be obtained, if the place

of the planet, by its longitude and latitude taken from an ephemeris, be aſcertained; and an artificial planet ſet thereto, in the manner in which we have directed the artificial moon to be placed upon the globe, or this laſt may occaſionally repreſent a planet.

198. Thus on the 18th day of June, A. D. 1769 new ſtile, being the firſt year after biſſextile, the ſun's place will be ♊, 27 deg. 22 min. the moon's place ♐ 18 deg. 0 min. her latitude north 0 deg. 30 min. The new moon about a ¼ of an hour paſt VI o'clock in the morning, to which places, if the artificial ſun and moon be ſet, a beginner may readily exerciſe himſelf in finding the proper anſwers agreeable to theſe data, by the directions in this problem.

Parallels of altitude.

199. The globe remaining rectified as in the laſt problem, the uppermoſt point repreſents a point in the heavens directly over our heads, which is called the *zenith*: and as the braſs quadrant is moveable about its upper end as a center, when that center is

fixed to the latitude of the place upon the ſtrong braſs meridian, it will be in the zenith, and the beginning of its graduations will coincide with the plane of the broad paper circle, which in theſe caſes repreſents the horizon of the place.

200. If the quadrant be moved about the globe, its firſt diviſion will deſcribe the horizon. And,

201. At the ſame time, all its intermediate diviſions, will deſcribe circles parallel to the horizon; the point marked 10 deſcribes a parallel of 10 degrees, the point marked 20 a parallel of 20 degrees, and ſo of any other point.

202. Theſe circles parallel to the horizon are called parallels of altitude.

Therefore theſe parallels ſhew the elevation of the ſun, moon, ſtars or planets, above the plane of the horizon.

And the quadrant itſelf in each caſe repreſents a ſecondary of the horizon.

PROBLEM XV.

To find the ſun's altitude at any time of the day.

203. Set the center of the artificial ſun to his place in the ecliptic upon the globe; and rectify it to the latitude and zenith, by problem xii. art. 166. bring the center of the artificial ſun under the graduated ſide of the ſtrong braſs meridian, and ſet the hour-index to that XII which is moſt elevated; turn the globe to the given hour, and move the graduated edge of the quadrant to the center of the artificial ſun; and that degree on the quadrant which is cut by the ſun's center, is the ſun's height at that time.

The artificial ſun being brought under the ſtrong braſs meridian, and the quadrant laid upon its center, will ſhew its meridian or greateſt altitude for that day.

If the ſun be in the equator, his greateſt or meridian altitude is equal to the elevation of the equator, which is always equal to the co-latitude of the place.

Azimuth or vertical circles.

204. An azimuth circle in aſtronomy, is the very ſame as a circle of poſition in geography; they being ſecondaries to the horizon, or great circles paſſing through the zenith of any place, and croſſing the horizon at right angles: either in the heavens called *azimuths*, or on the earth, *circles* of *poſition*.

205. Any azimuth may be repreſented by the quadrant of altitude, when the center upon which it turns, is ſcrewed to that point of the ſtrong braſs meridian; which anſwers to the latitude of the place, and the place brought into the zenith.

Suppoſe at London, if you bring the divided edge of the quadrant to 10 degrees on the inner edge of the broad paper circle, it will repreſent an azimuth of 10 degrees; if you ſet it to 20, it will repreſent an azimuth of 20 degrees; and ſo of any other.

206. If the quadrant of altitude be ſet to 0 degree, that is either upon the eaſt, or weſt points, of the broad paper circle, it

will

will then repreſent that azimuth, which is called the *prime vertical.*

PROBLEM XV.

To find the azimuth of the ſun or any ſtar.

207. Rectify the globe to the latitude and ſun's place, art. 166. 167. then turn it to the given hour, and bring the divided edge of the quadrant of altitude to the ſun's place in the ecliptic, or to the center of any ſtar, and it will croſs the horizon at the azimuth required.

The diſtance of that point of the horizon, in which the ſun appears to riſe or ſet, counted from the prime vertical, art. 206. or eaſt and weſt points of the horizon, is called the ſun's amplitude.

COROLLARY.

To find the angle of poſition, and the bearing of one place from another.

208. The angle of poſition is that formed between the meridian of one of the places,

and a great circle paſſing through the other place.

Rectify the globe to the latitude and zenith of one of the places, art. 166. 167. ſet the graduated edge of the quadrant to the other place, and the number of degrees contained between it and the ſtrong braſs meridian, is the meaſure of the angle ſought. Thus,

The angle of poſition between the meridian of Cape Clear in Ireland, and St. Auguſtine in Florida, is about 92 degrees north weſterly, but the angle of poſition between St. Auguſtine and Cape Clear, is only about 46 degrees north eaſterly.

Hence it is plain that the line of poſition, or azimuth, is not the ſame from either place to the other, as the romb-lines are.

To find the bearing of one place from another.

209. The bearing of one ſea-port from another is determined by a kind of ſpiral called a romb-line, paſſing from one to the other, ſo as to make equal angles with all the meridians it paſſeth by; therefore if

both places are ſituated on the ſame parallel of latitude, their bearing is either eaſt or weſt, from each other; if they are upon the ſame meridian, they bear north and ſouth from one another; if they lie upon a romb-line, their bearing is the ſame with it; if they do not, obſerve to which romb-line the two places are neareſt parallel, and that will ſhew the bearing ſought.

Thus the bearing of the Lizard Point from the iſland of Bermudas is nearly E N E; and that of Bermudas from the Lizard is W S W, both nearly upon the ſame romb, but in contrary directions.

A parallel ſphere

Is that poſition of the globe, where the poles are in the zenith and nadir, the equator in the horizon, and conſequently thoſe circles which are parallel thereto, are alſo parallel to the horizon.

The inhabitants of this ſphere, if any there be, muſt live upon the two terreſtrial poles.

A right

A right ſphere

Is that where the inhabitants ſee both poles in their horizon, the equator paſſing through their zenith and nadir, and all the circles parallel to the equinoctial perpendicular to their horizon.

Theſe people live upon the terreſtrial equator.

An oblique ſphere

Hath one of the poles of the globe above, the other under the horizon; the equator in all the caſes of this ſphere is half above, and half below the horizon, and the parallel circles cut the horizon obliquely.

The inhabitants of this ſphere are thoſe who live on all parts of the earth, except thoſe at the poles and upon the equator.

Of the twilight.

210. The morning-twilight or day-break begins when the ſun comes within 18 degrees of the horizon, and continues till ſun-riſing.

211. The evening-twilight begins at the time of the ſun ſetting, and continues till it is 18 degrees below the horizon.

212. For this purpoſe on our new globes, a wire-circle is fixed eighteen degrees below the ſurface of the broad paper circle; ſo that,

213. All thoſe places which are above the wire-circle, will have the twilight, but it will be dark to all places below it.

214. At the time of winter-ſolſtice, when the whole ſpace within the northern polar-circle is out of the ſun's light, the greater part of it enjoys the benefit of twilight; there being only about 5½ degrees round the pole that will be totally dark.

215. We have here only conſidered the twilight reflected to us from the earth's atmoſphere by the ſun himſelf; beſides which the body of the ſun is always encompaſſed with a ſphere of light, which being of a larger circumference than the ſun, muſt riſe before him, and ſet after him; which conſequently lengthens the twilight by illuminating our air, when the ſun is depreſſed too low to reach it with his own light: this ſeems to be the cauſe, why the ſun is

preceded by a luminous ſegment of a circle in the eaſt before his riſing, different from that light reflected by the atmoſphere from the body of the ſun; the like to which may be obſerved in the weſt after ſun-ſet.

To repreſent the earth's enlightened diſk by the terreſtrial globe.

216. We have already ſhewn how the earth's diurnal motion is repreſented by the motion of the terreſtrial globe about its axis from weſt to eaſt; and that the horary index will point upon the equator the 24 hours of one diurnal rotation, or any part of that time.

217. The broad paper circle, under this conſideration, will be now employed to repreſent a plane ſuppoſed to paſs through the center of the earth, perpendicular to a central ſolar ray: or in other words, perpendicular to a line ſuppoſed to be drawn from the center of the ſun to that of the earth at all times of the year.

In which caſe, the broad paper-circle divides that half of the earth's ſurface, which is illuminated by the ſun's rays, from the other hemiſphere which is not enlightened.

218. That the globe may appear to be ſo enlightened, conceive a ſun painted on the ceiling of the room in which you are, directly over the terreſtrial globe, and of the ſame diameter; from whence imagine an infinite number of parallel rays falling perpendicularly downwards upon the upper ſurface of the globe, which here repreſents the illuminated hemiſphere of the earth's enlightened diſk.

219. Whence it is plain, that the central ſolar ray is the only one, which paſſes through the centers of the ſun and earth, as well as the only ray that can poſſibly be perpendicular to the earth's ſurface; all other ſolar parallel rays will fall more and more oblique, as they are farther from the central ray, till their arrival at the edge of the enlightened diſk, here repreſented by the inner edge of the broad paper-circle, where they will become parallel to the horizons of all places then under the ſaid edge of the diſk.

220. In one diurnal revolution of the earth, the central ſolar ray deſcribes the

parallel of the ſun's declination; or rather that parallel, to the inhabitants of which the ſun that day will paſs directly vertical, or over their heads.

221. From this application of the terreſtrial globe, we ſee the natural cauſe of the different altitudes of the ſun at different times of the day, and at different ſeaſons of the year; which ariſe from the earth's daily rotative and progreſſive motion, &c.

222. When we view the globe in this poſition, we at once ſee the ſituation of all places in the illuminated hemiſphere, whoſe inhabitants enjoy the light of the day, while at the ſame time all thoſe places below the broad paper-circle, are deprived of the ſun's light and have only twilight ſo far as the wire circle, and all below that, have total darkneſs, when the moon does not ſhine on them.

223. And by obſerving the angles made by the meridians, drawn on the globe, cutting any parallel of latitude at the edge of the broad paper circle, with the ſtrong braſs meridian, we ſee the ſemi-diurnal arches continually decreaſe from the elevated pole,

till they come to the oppoſite part of the earth's enlightened diſk.

PROBLEM XVII.

To rectify the terreſtrial globe, that the enlightened half of the earth's ſurface may be all above the broad paper circle for any time of the year; the ſun being ſuppoſed in the zenith.

225. On the backſide of the ſtrong braſs meridian, and on each ſide of the north pole, are graduated in two concentric ſpaces the months and days of the year.

226. Bring the day of the month to coincide with the broad paper circle, and the terreſtrial globe is rectified.

227. When the globe is thus rectified, that degree and minute upon the graduated ſide of the braſs meridian, which is then cut by the plane of the broad paper circle, is the diſtance of the ſhade of extuberancy upon the earth's diſk, reckoned from the

pole, and is equal to the ſun's declination for that day: and is therefore alſo equal to the latitude counted from the equator of all thoſe places to whom the ſun is vertical; and this point on the braſs meridian repreſents the central ſolar ray deſcribing the parallel of the day.

228. If now the globe be turned from weſt to eaſt, all thoſe places which arrive at the weſtern edge of the broad paper circle, are paſſing out of the twilight into the ſun's light; the ſun then appears riſing to all thoſe inhabitants.

229. At the ſame time, if you look upon the eaſtern edge of the broad paper circle, it will cut all thoſe places which are then paſſing, from the ſun's light into the twilight; whoſe inhabitants will ſee the ſun ſetting, and enjoy the twilight until they arrive at the wire circle, which is placed 18 degrees below the illuminated diſk, at which time they enter into total darkneſs.

230. The graduated ſide of the ſtrong braſs meridian ſhews, at the ſame time, all thoſe places which have mid-day or noon.

231. If the horary index be ſet to XII, when any particular place is brought under

the graduated ſide of the ſtrong braſs meridian, it will ſhew as you turn the globe from weſt to eaſt, the preciſe time of ſun riſing, ſetting, &c. at that place.

232. The horary index will alſo ſhew how long a place is moving from the weſt to the eaſt ſide of the illuminated diſk, here repreſented by the broad paper circle, and thence the length of the day and night; it will alſo point out the length of the twilight by the time that the place is paſſing from the twilight circle to the edge of the diſk on the weſtern ſide, or from the edge of the diſk to that circle on the eaſtern ſide, and thence the length of time we enjoy a whole artificial day.

We ſhall proceed to exemplify theſe particulars at the times of equinox and ſolſtice.

PROBLEM XVIII.

The times of equinox.

233. The ſun has no declination at the times of equinox, conſequently there muſt be no elevation of the poles.

234. Bring the day of the month on the backſide of the ſtrong braſs circle, in which the ſun enters the firſt point of aries or libra, into the plane of the broad paper circle, and then the two poles of the globe will be in that plane alſo; and all thoſe circles which are parallel to the equator will cut the plane of that broad circle at right angles, and the globe will then repreſent a right ſphere.

235. If you now turn the globe from weſt to eaſt, it will plainly appear that all places upon its ſurface are twelve hours above the broad paper circle and as many below it, which ſhews the nights are equal to the days to all the inhabitants of the earth; that is, they are illuminated by the ſun's rays twelve hours, whence theſe are called the times of equinox, which happens twice every year; the firſt is the *autumnal*, the ſecond the *vernal equinox*.

236. At theſe times the ſun appears to riſe and ſet at the ſame inſtant to all places in the ſame meridian.

237. But their twilight is longer as their ſituation is nearer to either pole, in ſo much that within 18 degrees of the poles, their

twilight is 12 hours, conſequently there is no dark night in thoſe places at the times of equinox: when at the ſame time thoſe places under the equator have only one hour and 12 minutes twilight; ſo that their artificial day is about 14 h. 24 min. at theſe two ſeaſons of the year.

238. Thus if London, and Mundfort on the Gold Coaſt, be brought to the ſtrong braſs meridian, the graduated ſide of which is the horary index; in other caſes the hour index ſet to that XII which is moſt elevated, and if then they be brought to the weſt ſide of the broad paper circle, the index will then point to VI o'clock for ſun riſing, and to VI for ſun ſetting, when theſe places are brought to the eaſtern ſide.

239. Alſo if London be turned from the weſt towards the eaſt, and the hour index be ſet to XII as before, then turning on till the iſland of Jamaica comes to the meridian, it ſhews on the equator the hour after noon at London, when it is noon at Jamaica, or that London paſſes under the meridian about 5 h. 4. min. before Jamaica arrives at it.

PROBLEM XIX.

The ſummer-ſolſtice.

240. Rectify the globe to the extremity of the diviſions for the month of June; then that part of the earth's ſurface, which is within the northern polar-circle, will be all illuminated by the ſun, and the inhabitants thereof will have continual day.

241. But all that ſpace which is contained within the ſouthern polar-circle, will be at the ſame time in the ſhade, and have continual night.

242. In this poſition of the globe, we ſee how the diurnal arches of the parallels of latitude decreaſe, as they are more and more diſtant from the elevated pole.

243. If any place be brought under the graduated ſide of the ſtrong braſs meridian, and the horary index be ſet to that XII which is moſt elevated, and if that place be brought to the weſtern ſide of the broad paper circle, the hour index will ſhew the time of ſun riſing; and when moved to the eaſtern edge, the index points to the time of ſun ſetting; the length of the day is ob-

tained

tained by the time ſhewn by the horary index, while the globe is turned from the eaſt to the weſt ſide of the illuminated diſk.

244. Thus it will be found that at London the ſun riſes about 15 minutes before IV in the morning, and ſets about 15 minutes after VIII at night.

245. Alſo at the following places it will be nearly at the times expreſſed.

	☼ Riſing.		☼ Setting.		Length of Day.		Twi-light.	
	h.	m.	h.	m.	h.	m.	h.	m.
Cape Horn	8	44	3	16	6	32	2	35
Cape of Good-Hope	7	09	4	51	9	42	1	43
Rio de Janario in Brazil, near the tropic of capricorn	6	42	5	19	10	38	1	23
The iſland of St. Thomas at the equator	6	0	6	0	12	0	1	20
Cape Lucas, the ſouthermoſt point of California, at the tropic of cancer.	5	12	6	48	13	36	1	35

246. We alſo ſee at the ſame time, when the ſun riſes at London, it riſes at the Iſland of Sicily in the Mediterranean, and at the Iſland of Madagaſcar.

247. And at the ſame time, when the ſun ſets at London, it is ſetting at the Iſland of Madeira, and at Cape Horn.

248. And when it is ſun-ſetting at the Iſland of Borneo in the Eaſt Indies, the ſun is riſing at Florida in America.

PROBLEM XX.

Winter-ſolſtice.

250. Rectify the globe to the extremity of the diviſions for the month of December, or to 23½ degrees ſouth declination.

251. At this ſeaſon it will be apparent, that the whole ſpace within the ſouthern polar-circle is in the ſun's light, and enjoys continual day, whilſt that of the northern polar-circle is in the ſhade, and has continual night.

Then if the globe be turned as before, the horary index will ſhew, that at the ſeveral places before mentioned, their days will be reſpectively equal to what their nights were at the time of the ſummer-ſolſtice.

It will appear to be ſun ſetting at the time it was then ſun riſing; and on the contrary ſun riſing at the time it then appeared to ſet.

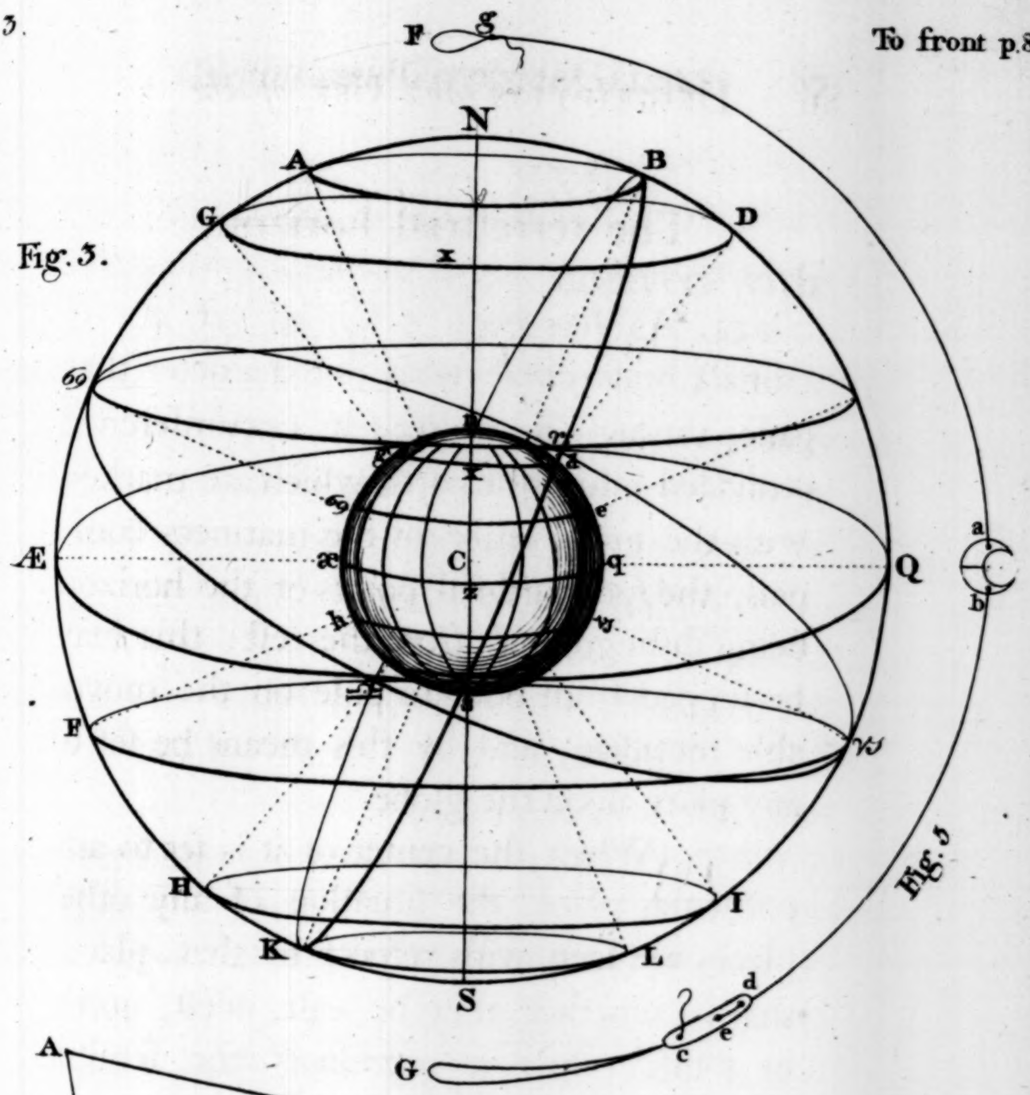
The terreſtrial horizon,

252. As has been deſcribed art. 40. is a ſmall braſs circle with one diameter that paſſes through its center; its circumference is divided into eight parts, which are marked with the initial letters of the mariners compaſs, the four cardinal points of the horizon being diſtinguiſhed from the reſt; this may be ſlipped from pole to pole on the moveable meridian, and by this means be ſet to any place upon the globe.

253. When the center of it is ſet to any particular place, the ſituation of any other places are ſeen with reſpect to that place; that is, whether they be eaſt, weſt, north, or ſouth; thus it repreſents the ſenſible horizon.

254. Its uſe will ſhew why the ſun appears at different altitudes and azimuths, although he is ſuppoſed to be always in the ſame place.

Fig. 3.



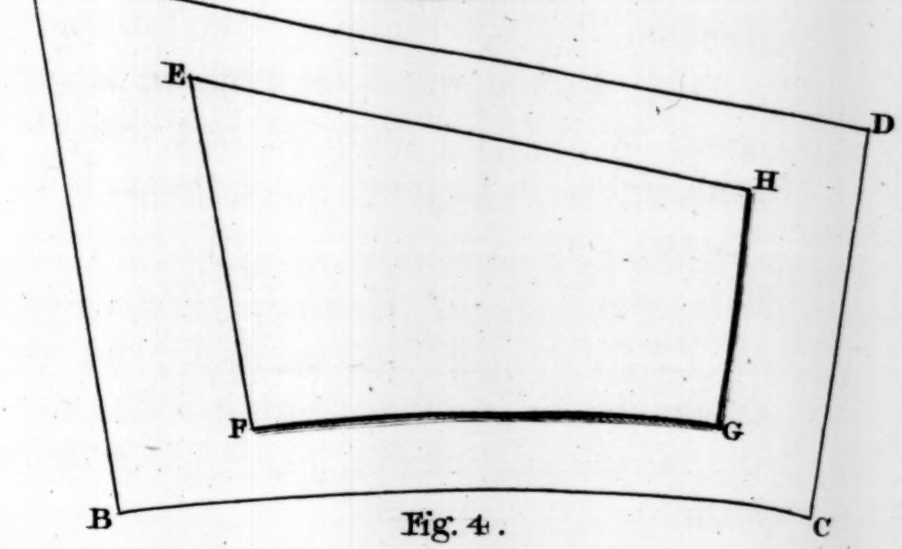


Fig. 4.

PROBLEM XXI.

The ſun's altitude as obſerved with a terreſtrial or viſible horizon.

255. The altitude of the ſun is greater or leſs, according as one of the parallel right lines or rays, coming from the ſun to us, is farther from or nearer to our horizon.

Apply the terreſtrial horizon to London, the ſun being ſuppoſed in the zenith, or on the ceiling directly over the globe.

256. If then from London a line paſs vertically upwards, the ſun will be ſeen from London in that line.

257. At ſun riſing, when London is brought to the weſt edge of the broad paper circle, the ſuppoſed line will be parallel to the terreſtrial horizon, and from London will be then ſeen in the horizon.

258. As the globe is gradually turned from weſt towards the eaſt, the horizon will recede from the line which paſſes perpendicularly upwards; for the line in which the ſun was then ſeen, ſeems to glide farther and farther from the terreſtrial horizon; that is, the ſun's altitude increaſes as gradually

dually as that line declines from the terreſtrial horizon.

259. When the horizon, and the line which goes from London vertically upwards, are arrived at the ſtrong braſs meridian, the ſun is then at his greateſt or meridian altitude for that day: then the line and horizon are at the largeſt angle they can make that day with each other.

260. After which, the motion of the globe being continued, this angle between the terreſtrial horizon and the line, which goes from London vertically upwards, continually decreaſes, until London arrives at the eaſtern edge of the broad paper circle, its horizon then becomes vertical again, and parallel to the line which goes vertically upwards, and will then appear in the horizon, and be ſeen to ſet.

PROBLEM XXII.

The ſun's meridian-altitude at three different ſeaſons.

261. Rectify the globe to the time of winter-ſolſtice, art. 250. and place the center of the viſible horizon on London.

When London is at the graduated edge of the ſtrong braſs meridian, the line which goes vertically upwards, makes an angle of about 15 degrees; this is the ſun's meridian-altitude at that ſeaſon to the inhabitants of London.

262. If the globe be rectified to the time of equinox, art. 233. the horizon will be farther ſeparated from the line which goes vertically upwards, and makes a greater angle therewith, which will be about 38½ degrees; this is the ſun's meridian-altitude at the time of equinox at London.

263. Again rectify the globe to the ſummer-ſolſtice, art. 240. and you will find the viſible horizon recede farther from the line which goes from London vertically upwards; and the angle it then makes with the horizon, is about 62 degrees, which ſhews the ſun's meridian-altitude at the time of the ſummer-ſolſtice.

From hence flows the following arithmetical

PROBLEM

PROBLEM XXIII.

To find the ſun's meridional altitude univerſally.

264. Add the ſun's declination to the elevation of the equator, if the latitude and declination are both on the ſame ſide.

If on contrary ſides, ſubſtract the declination from the elevation of the equator, and you obtain the ſun's meridian-altitude.

	°	'
Thus, the elevation of the equator at London	38	28
Sun's declination May 20th	20	8
Their ſum is the ſun's meridian-altitude for that day at London	58	36
Again, to the elevation of the equator at London	38	28
Add the ſun's greateſt declination at the time of the ſummer-ſolſtice	23	29
Their ſum is the ſun's greateſt meridian-altitude at London,	61	57

Whence alſo flows another method,

To

To find the ſun's greateſt and leaſt altitude univerſally.

265. Add the ſun's declination to and ſubſtract it from the elevation of the equator, their ſum and difference will be the ſun's meridional altitudes, when he hath the ſame declination either north or ſouth.

	°	′
Thus, to and from the elevation of the equator	38	28
Add and ſubſtract the ſun's declination.	20	8
Their ſum is the ſun's meridian-altitude in ſummer	58	36
Their difference his meridian-altitude in winter	18	20

having the ſame declination one north, the other ſouth.

PROBLEM XXIV.

The ſun's azimuth compared with the viſible horizon.

266. Imagine the ſun, as we have done before, to be painted on the ceiling directly

over the globe, art. 218. and a line going vertically upwards towards the ſun from any place on the ſurface of the globe.

If to that place you apply the viſible horizon, that point of it which a vertical line is neareſt to at any time, ſhews the ſun's azimuth at that time: and we muſt alſo obſerve, that that point of the terreſtrial or viſible horizon, to which a vertical line is neareſt, is always the moſt elevated point.

267. Rectify the globe to the poſition of a right ſphere, art. 233. and apply the viſible horizon to London. When London is at the weſtern edge of the broad paper circle, which ſituation repreſents the time when the ſun appears to riſe, the eaſtern point of the viſible horizon being then moſt elevated, ſhews that the ſun at his riſing is due eaſt.

Turn the globe till London comes to the eaſtern ſide of the paper circle, then the weſtern point of the viſible horizon will be moſt elevated, and ſhew that the ſun ſets due weſt.

268. If the globe be rectified into the poſition of an oblique ſphere, and London be brought to the eaſtern or weſtern ſide of

the broad paper circle, the vertical line will depart more or leſs from the eaſt and weſt points: in which caſes the ſun is ſaid to have more or leſs amplitude either north or ſouth, as this departure tends to either of thoſe two cardinal points.

As the globe is turned to any particular time of the day, we ſhall have the ſun's azimuth upon that point of the viſible horizon which is moſt elevated, and this will be the point where a line going towards the ſun is neareſt to a vertical line; thus if a line going towards the ſun be neareſt the ſouth-eaſt point, the ſun is then ſaid to have 45 degrees azimuth eaſtward, that point being 45 degrees from the meridian.

269. In all poſitions of the globe in north latitudes, when London is brought to the graduated edge of the ſtrong braſs meridian, the moſt elevated point of the viſible horizon will always be the ſouth point of it, which ſhews, that the ſun, at all ſeaſons of the year, will appear to the ſouth of the terreſtrial horizon in all places included in the northern temperate zone; but to the north of it at thoſe places within the ſouthern temperate zone.

270. The ancient diſtinction of the different places on the earth, according to the diverſity of their noon-ſhadows.

PROBLEM XXV.

The aſcii, or thoſe who project no ſhade at noon

271. Rectify the globe by problem xix. art. 240. to the time of the ſummer-ſolſtice, and apply the terreſtrial horizon to any place ſituated on the tropic of cancer, as Kanton in China, and obſerve the ſun's meridian-altitude with it, by bringing its center under the graduated edge of the ſtrong braſs meridian, art. 255. it will then appear, that a line going vertically upwards, will be perpendicular to it, conſequently the ſun will be at that time directly over the heads of the inhabitants of Kanton, and project no ſhadow; therefore they are aſcii, their noon-ſhadow being directly under them.

272. At all other times of the day their ſhadow is projected, in the morning directly weſt, and in the evening directly eaſt.

273. The ſame thing will happen to all the inhabitants, who live between the tropic of cancer and that of capricorn, if the terreſtrial horizon be gradually removed from parallel to parallel within theſe limits, and the globe rectified according to the day of the month as before directed; by bringing the ſenſible horizon to the graduated ſide of the ſtrong braſs meridian, to obſerve the ſun's meridian-altitude, we ſhall find him appear to be 90 degrees high or vertical at noon to every place between the tropics; all the inhabitants being aſcii twice a year, except thoſe on the tropics themſelves, who are aſcii only once a year.

PROBLEM

PROBLEM XXVI.

The inhabitants of all places between the tropics of cancer and capricorn, are not only aſcii, but amphiſcii, whoſe noon-ſhadows are projected ſometimes towards the north, at other times towards the ſouth.

274. Place the ſenſible horizon on the equator, and rectify the globe to the time of the equinox, art. 223. at which time the equatorial inhabitants are aſcii at noon, having the ſun full eaſt of them all the morning, and full weſt all the afternoon.

275. The eaſtern point of the viſible horizon will be always uppermoſt, or moſt elevated, as the globe is moved from weſt to eaſt, till it comes to the ſtrong braſs meridian; and after it has paſſed this, the weſtern point will be moſt elevated.

276. The ſenſible horizon remaining on the equator, rectify the globe to the time of the ſummer-ſolſtice, art. 240. and you

will find the north point at noon will be moſt elevated; which plainly ſhews, that the inhabitants of the equator will ſee the ſun full north at that ſeaſon, and that their ſhade will be projected ſouthwards.

278. If the globe be rectified to the winter-ſolſtice, the ſouth point will be moſt elevated, and the inhabitants will ſee the ſun on their ſouth ſide, which will project their ſhadows northwards.

279. Heteroſcii, are thoſe who live between the tropics and polar-circles, whoſe noon ſhadows are projected one way only.

Thoſe in north latitude have their noon ſhadows projected northwards; the ſun at that time being always in the ſouth.

And thoſe in ſouth latitude have their noon-tide ſhadows projected ſouthwards; the meridian ſun always appearing to them in the north.

280. Periſcii are thoſe who live within the polar-circles, the ſun going continually round them, their ſhadow muſt neceſſarily go round them alſo.

If the ſenſible or terreſtrial horizon be applied to any of theſe places, and the globe rectified according to the preceding directions,

tions, it will ſhew, that the ſun appears to be more elevated at one time of the day than at another; and alſo, which way at all times the noon and other ſhadows are caſt.

281. Antæci are two oppoſite nations lying in or near the ſame meridian, one of them in north, the other in ſouth latitude; they have both the ſame longitude, and equal latitudes, but on oppoſite ſides of the equator.

282. Periæci are two nations ſituated on oppoſite ſides of the globe, in the ſame parallel of latitude.

Therefore their longitudes muſt differ 180 degrees.

283. Antipodes are two nations diametrically oppoſite.

284. A ſtrait line paſſing from one to the other muſt conſequently paſs through the center, and therefore become a diameter of the globe.

Their longitudes and latitudes are both oppoſite.

285. Theſe are exemplified by rectifying the globe into the poſition of a right ſphere, art. 233. and bringing the nations under

conſideration to the edge of the broad-paper circle. Thus,

The inhabitants of the eaſtern parts of Chili are Antæci to thoſe of New England; whoſe Periæci live in the northern parts of China, who are alſo Antipodes to the inhabitants of Chili.

We ſhall now proceed to exemplify the former precepts in a few particular problems.

PROBLEM XXVII.

To find all thoſe places on the globe, over whoſe zenith the ſun will paſs on any given day.

286. Rectify the terreſtrial globe, art. 224. by bringing the given day of the month, on the backſide of the ſtrong braſs meridian, to coincide with the plane of the broad-paper circle, and obſerve the elevation of the pole on the other ſide, and that degree counted from the equator on the ſtrong braſs meridian, towards the elevated pole, is the point over which the ſun is vertical. Now turning the globe, all thoſe

places which paſs under this point, have the ſun directly over their heads on the given day.

Thus bring the 11th day of May, into the plane of the broad-paper circle, and the ſaid plane will cut 18 degrees for the elevation of the pole, which is equal to the ſun's declination for that day; which counted on the ſtrong braſs meridian towards the elevated pole, is the point over which the ſun will be vertical. Now turning the globe round, we ſhall find that Amalagan, one of the Ladrone iſlands, the northern part of Manilla, the middle of Siam, a great part of Africa, and St. Anthony, one of the Cape Verd Iſles, the ſouthern ſide of the iſlands Porto-rico and Domingo, and the northern part of the iſland of Jamaica, &c. have all of them the ſun in their zenith on the 11th of May.

Hence when the ſun's declination is equal to the latitude of any place in the torrid zone, the ſun will be vertical to thoſe inhabitants that day.

Hence alſo we derive the following

PROBLEM XXVIII.

To find the ſun's declination, and thence the parallel of latitude correſponding therewith, upon the terreſtrial globe.

287. Find the ſun's place upon the broad-paper circle for any given day, art. 18. and ſeek that place in the ecliptic line upon the globe; this will ſhew the parallel of the ſun's declination among the dotted lines, which is alſo the correſponding parallel of latitude; therefore all thoſe places through which this parallel paſſes, have the ſun in their zenith at noon on the given day.

PROBLEM XXIX.

To find thoſe two days on which the ſun will be vertical to any place between the tropics.

288. That parallel of declination which paſſes through the given place, will cut the ecliptic line upon the globe in two points,

which denote the ſun's place, againſt which, on the broad-paper circle, are the days and months required.

PROBLEM XXX.

The day and hour at any place being given, to find where the ſun is vertical at that time.

289. Let the given place be London, and time the 11th day of May at 4 minutes paſt V in the afternoon.

Rectify the globe to the day of the month, art. 224. and you have the ſun's declination 18 degrees north; bring London to the meridian, and ſet the horary index to XII, turn the globe till the index points to the given hour on the equator, 4 minutes paſt V, then Port-Royal in Jamaica will be under the 18th degree of the graduated ſide of the ſtrong braſs meridian, which is the place where the ſun is vertical at that inſtant.

PROBLEM XXXI.

The time of the day at any one place being given, to find all thoſe places in which the ſun is then riſing, ſetting, on the meridian, and where he is vertical; likewiſe thoſe places where it is midnight, twilight, and dark-night, at the ſame inſtant; as well as thoſe places in which the twilight is beginning and ending; and alſo to find the ſun's altitude at any hour in the illuminated, and his depreſſion in the obſcure hemiſphere.

290. Rectify the globe to the day of the month, art. 224. on the backſide of the ſtrong braſs meridian, and the ſun's declination for that day, which is equal to the elevation of the pole, is given upon the graduated ſide of the braſs meridian, by its

coincidence with the plane of the broad-paper circle; bring the given place to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII, upon the equator, turn the globe from weſt to eaſt until the horary index points to the given time. Then,

All thoſe places which lie in the plane of the weſtern ſide of the broad-paper circle ſee the ſun riſing, and at the ſame time thoſe on the eaſtern ſide of it ſee him ſetting.

It is then noon to all the inhabitants of thoſe places under the upper half of the graduated ſide of the ſtrong braſs meridian, whilſt at the ſame time thoſe under the lower half have mid-night.

All thoſe places which are then between the upper ſurface of the broad-paper circle, and the wire-circle under it, are in the twilight, which begins to all thoſe places on the weſtern ſide that are immediately under the wire-circle; to them it is the dawning of the day; its end is at all thoſe places in the plane of the paper-circle on which the ſun has juſt begun to riſe.

The contrary happens on the eaſtern ſide; the twilight is juſt beginning to thoſe places in which the ſun is ſetting, and its end is at the place juſt under the wire-circle.

And all thoſe places which are under the twilight wire-circle have dark night, unleſs the moon is favourable to them.

All places in the illuminated hemiſphere have the ſun's altitude equal to their diſtance from the edge of the enlightened diſk, which is known by fixing the quadrant of altitude to the zenith, and laying its graduated edge over any particular place.

The ſun's depreſſion is obtained in the ſame manner by fixing the center of the quadrant at the nadir.

PROBLEM XXXII.

To find the time of the ſun's riſing and ſetting, the length of day and night on any day in the year in any place, whoſe latitude lies between the polar-circles, and alſo the length of the ſhorteſt day and night

night in any of thoſe latitudes, and the climate they are in.

291. Rectify the celeſtial globe to the latitude of the given place, art. 166. bring the artificial ſun to his place in the ecliptic for the given day of the month; and then bring its center under the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to that XII which is moſt elevated.

Then bring the center of the artificial ſun to the eaſtern part of the broad-paper circle, which in this caſe repreſents the horizon, and the horary index ſhews the time of the ſun-riſing; turn the artificial ſun to the weſtern ſide, and the horary index will ſhew the time of the ſun-ſetting.

Double the time of ſun-riſing is the length of the night, and the double of that of ſun-ſetting is the length of the day.

Thus on the 5th day of June, the ſun riſes at 3 h. 40 min. and ſets at 8 h. 20 m. by doubling each number it will appear, that the length of this day is 16 h. 40 m. and that of the night 7 h. 20 m.

The longeſt day at all places in north latitude, is when the ſun is in the firſt point of cancer. And,

The longeſt day to thoſe in ſouth latitude, is when the ſun is in the firſt point of capricorn.

Wherefore the globe being rectified as above, and the artificial ſun placed to the firſt point of cancer, and brought to the eaſtern edge of the broad-paper circle, and the horary index being ſet to that XII which is moſt elevated, on turning the globe from eaſt to weſt, until the artificial ſun coincides with the weſtern edge, the number of hours counted, which are paſſed over by the horary index, is the length of the longeſt day; their complement to twenty-four hours gives the length of the ſhorteſt night.

292. If twelve hours be ſubſtracted from the length of the longeſt day, and the remaining hours doubled, you obtain the climate mentioned by ancient hiſtorians.

PROBLEM

PROBLEM XXXIII.

To find all thoſe places within the polar-circles, on which the ſun begins to ſhine, the time he ſhines conſtantly, when he begins to diſappear, the length of his abſence, as well as the firſt and laſt day of his appearance to thoſe inhabitants. The day of the month, or latitude of the place, being given.

293. Bring the given day of the month on the backſide of the ſtrong braſs meridian, to the plane of the broad-paper circle, the ſun is juſt then beginning to ſhine on all thoſe places which are in that parallel, juſt touched by the edge of the broad-paper circle; and will for ſeveral days ſeem to ſkim all around, and but a little above the horizon, juſt as it appears to us at its ſetting; but with this obſervable difference, that whereas our ſetting ſun appears in one part

of the horizon only, by them it is ſeen in every part thereof; from weſt to ſouth, thence eaſt to north, and ſo to the weſt again.

294. Or if the latitude was given, elevate the globe to that latitude, and on the backſide of the ſtrong braſs meridian you obtain the day of the month, then all the other requiſites are anſwered as above.

295. As the two concentric ſpaces which contain the days of the month on the backſide of the ſtrong braſs meridian, are graduated to ſhew the oppoſite days of the year, at 180 degrees diſtance, when the given day is brought to coincide with the broad-paper circle, it ſhews when the ſun begins to ſhine on that parallel, and the plane of the ſaid broad-paper circle cuts the day of the month on the oppoſite concentric ſpace, when the ſun begins to diſappear to thoſe inhabitants; thus the length of the longeſt day is obtained, by reckoning the number of days between the two oppoſite days found as above; and their difference from 365 days gives the length of their longeſt night.

The firſt and laſt day of his appearance on that circum-polar parallel, are thoſe expreſſed by the oppoſite days; his continuance to ſhine on thoſe places is the length of their longeſt day, and his abſence from them is the length of their ſhorteſt night.

PROBLEM XXXIV.

To find the length of any day in the year, in any latitude.

296. Elevate the celeſtial globe to the latitude, and ſet the center of the artificial ſun to his place upon the ecliptic line on the globe for the given day, and bring its center to the graduated ſide of the ſtrong braſs meridian, placing the horary index to that XII which is moſt elevated; then turn the globe till the artificial ſun cuts the eaſtern edge of the broad-paper circle, and the horary index will ſhew the time of ſun-riſing; turn it to the weſtern ſide and you obtain the hour of ſun-ſetting.

The length of the day and night will be obtained, by doubling the time of ſun-riſing and ſetting, as before.

PROBLEM XXXV.

To find the length of the longeſt and ſhorteſt days in any latitude.

297. Elevate the globe according to the latitude, art. 166. and place the center of the artificial ſun for the longeſt day upon the firſt point of cancer, but for the ſhorteſt day on the firſt point of capricorn, then proceed as in the laſt problem.

298. But if the place hath ſouth latitude, the ſun is in the firſt point of capricorn on their longeſt day, and in the firſt point of cancer on their ſhorteſt day.

Note, This problem is only to be uſed in ſuch latitudes as lie between the northern and ſouthern polar-circles.

PROBLEM XXXVI.

To find the latitude of a place, in which its longeſt day may be of any given length between twelve and twenty-four hours.

299. Set the artificial ſun to the firſt point of cancer; bring its center to the graduated ſide of the ſtrong braſs meridian, and put the horary index to XII; turn the globe till it points to half the number of given hours and minutes; then elevate or depreſs the poles, till the artificial ſun coincides with the broad-paper circle, and that elevation of the pole is the latitude required.

PROBLEM XXXVII.

To find the diſtance between any two places.

300. Lay the graduated edge of the quadrant of altitude over both places, and the number of degrees between them is their diſtance, which is reduced to geographical

miles, by reckoning 60 to a degree, or to Engliſh miles reckoning 69½ to one degree.

PROBLEM XXXVIII.

To find all thoſe places which are at the ſame diſtance from a given place.

301. Rectify the globe by problem XII, art. 166. and bring the given place to the ſtrong braſs meridian, over which ſcrew the center upon which the quadrant of altitude turns; now move the quadrant round, and all thoſe places, that are cut by any one point on the quadrant, are equally diſtant from the given place.

PROBLEM XXXIX.

To ſhew at one view upon the terreſtrial globe for any given place, the ſun's meridian altitude, his amplitude or point of the com-

paſs,

paſs, on which he riſes and ſets every day in the year.

302. Rectify the globe to the latitude, art. 166. of the given place; bring that place to the ſtrong braſs meridian, and ſet the horary index to XII, ſcrew the quadrant of altitude to the zenith of the broad paper circle, you will at one view ſee the ſun's meridian altitude on every degree of the ſun's declination for the whole year, cut by the dotted parallels on the graduated edge of the quadrant of altitude; alſo theſe dotted parallels at the ſame inſtant cut the edge of the broad paper circle now repreſenting the horizon, in the point of the compaſs or amplitude, on which the ſun is ſeen to riſe on the eaſt or to ſet on the weſt ſide of the horizon, for every degree of declination throughout the year.

303. If you trace any of thoſe parallels to the ecliptic line, you have the ſun's place when he is upon that declination, and thence the day and month upon the broad paper circle.

304. Alſo, knowing the ſun's place in the ecliptic line, that ſhews the ſun's decli-

nation for that time amongſt the dotted parallels.

PROBLEM XL.

To ſhew at one view upon the terreſtrial globe the length of the days and nights at any particular place, for all times of the year.

305. Rectify the globe to the latitude of the place, art. 166. and the broad paper circle will repreſent the horizon, and the upper parts of the dotted parallels of declination, which are here alſo parallels of latitude, will repreſent the diurnal arches.

Whence we may obtain the number of hours each of them contain, which is the ſolution of the problem. To illuſtrate which,

306. Elevate the globe to the poſition of a right ſphere, art. 233. and you will with one glance of the eye, ſee that all the dotted parallels of declination, as well as the equator itſelf, are cut by the broad paper circle into two equal parts.

307. There-

307. Therefore the inhabitants on the equinoctial line have their days and nights twelve hours long; that is, the ſun is never more nor never leſs than twelve hours above their horizon, during his apparent paſſage, from the tropic of cancer to the tropic of capricorn, and thence to cancer again.

308. All the fixed ſtars have the ſame apparent motion to the equatorial inhabitants; that is, they riſe and ſet, continue above and are depreſſed below the horizon of any place upon the equator, exactly twelve hours.

309. Raiſe the north pole of the globe a few degrees of latitude at a time, and you will ſee the diurnal arches will increaſe in length, until the pole is elevated to 66½ degrees above the horizon: then the parallel of the ſun's greateſt declination will be as far from the equator as the place itſelf is from the pole; and this parallel is the tropic of cancer, which will juſt touch the horizon in the north point.

310. And on the contrary, we may obſerve, that the ſouthern parallels of declination continually ſhorten, as the northern

ones lengthen, until they come to the tropic of capricorn.

311. Rectify the globe to the latitude of London 51½ degrees north: when the ſun is in the tropic of cancer, the day is about 16½ hours, as he recedes from thence, the days ſhorten, as the lengths of the diurnal arches of the parallels ſhorten; until the ſun comes to capricorn, and then the days are at the ſhorteſt, being of the ſame length with the nights, when the ſun was in cancer, viz. about 7½ hours.

312. Rectify the globe to the latitude of the northern polar circles, and you will find, when the ſun is in cancer, he touches the horizon on that day without ſetting, being completely twenty-four hours above the horizon: and when he is in capricorn, he once appears in the horizon, but does not riſe for the ſpace of twenty-four hours; when he is upon any other parallel of declination, the days are longer or ſhorter, as that parallel is nearer to or farther from the equator.

313. Elevate the globe to the latitude of 80 degrees north, at which time let the ſun's declination be 10 degrees north, he

then

then apparently ſeems to turn round above the horizon without ſetting, and never ſets from this point to cancer, until in his return, after he has again paſſed this parallel of declination.

314. In the ſame manner when his declination is 10 degrees ſouth, he is juſt ſeen at noon in the horizon, and diſappears from that time in his ſoutherly motion, till his return to the ſame point.

315. Elevate the north pole to 90 degrees or in the zenith, then the globe will be in the poſition of a parallel ſphere, and the equinoctial line will coincide with the plane of the horizon, conſequently all the northern parallels are above, and all the ſouthern parallels below the horizon; therefore the polar inhabitants, if any there be, have but one day and one night throughout the year; their day when the ſun is in his northern, and their night when he is in his ſouthern declination.

This method of rectifying the globe for north latitude holds good in ſouth latitude alſo, by elevating the ſouth pole.

PROBLEM XLI.

To find what conſtellation any remarkable ſtar, ſeen in the firmament, belongs to.

316. Bring the ſun's place in the ecliptic for that day to the ſtrong braſs meridian, and ſet the horary index to that XII which is moſt elevated, the celeſtial globe being rectified to the latitude, turn the globe till it points to the preſent hour; and by the help of the mariners compaſs and attending to the variation, ſet the north pole of the globe towards the north pole of the heavens.

The ſtar upon the globe (if you conceive yourſelf in the center) which directs towards that point in the heavens, in which the ſtar you want to know is ſeen, is the ſtar required.

At the ſame time, by comparing the ſtars in the heavens with thoſe upon the globe, the other ſtars and their conſtellations may be eaſily known; whereby you will be enabled any ſtar-light night, to point out many of thoſe ſtars called correſpondents to various places on the earth.

PROBLEM XLII.

To find at what hour any known ſtar paſſes the meridian on any day in the year.

317. Rectify the globe to the latitude, art. 166. and ſet the artificial ſun to his place in the ecliptic, bring its center under the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII, then turn the globe till the ſtar comes to the meridian, and the horary index will point upon the equator the hour on which that ſtar will be upon the ſouth part of the meridian.

If you turn the globe on till the center of the artificial ſun is under that graduated ſide of the braſs meridian, which is below the elevated pole, all thoſe ſtars, which are then cut by that ſide of the meridian above the ſaid pole, will tranſit the meridian at midnight.

PROBLEM

PROBLEM XLIII.

To find on what day of the year any ſtar paſſes the meridian at any propoſed hour of the night.

318. Bring the ſtar to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to the propoſed hour, then turn the globe till the index points to XII, and that degree on the ecliptic, which is cut by the meridian, is the ſun's place, againſt which, in the kalendar upon the broad-paper circle, is the day of the month.

PROBLEM XLIV.

To trace the circles of the ſphere in the ſtarry firmament.

319. We ſhall ſolve this problem for the time of the autumnal equinox, becauſe that interſection of the equator and ecliptic will be directly under the depreſſed part of the meridian about midnight, and then the

oppoſite interſection will be elevated above the horizon; and alſo becauſe our firſt meridian upon the terreſtrial globe paſſing through London, and the firſt point of aries. When both globes are rectified to the latitude of London, and to the ſun's place by problem XII, art. 166. 167. and the firſt point of aries brought under the graduated ſide of each of their meridians, we ſhall have the correſponding face of the heavens and the earth repreſented, as they are with reſpect to each other at that time, and the principal circles of each ſphere will correſpond with each other.

320. The horizon is then diſtinguiſhed, if we begin from the north and count weſtward, by the following conſtellations; the hounds and waiſt of Bootes, the northern crown, the head of Hercules, and ſhoulders of Serpentarius, Sobieſki's ſhield, it paſſes a little below the feet of Antinous, and through thoſe of capricorn, through the Sculptore's frame, Eridanus, the ſtar Rigell in Orion's foot, the head of Monoceros, the crab, the head of the little lion, and lower part of the great bear.

321. The *meridian* is then repreſented by *the equinoctial colure*, which paſſes through the ſtar marked δ in the tail of the little bear, under the north pole, the pole ſtar, one of the ſtars in the back of Caſſiopea's chair marked β, the head of Andromeda, the bright ſtar in the wing of Pegaſus marked γ, and the extremity of the tail of the whale.

322. *The equator*, that part of it which is then above the horizon, is repreſented on the weſtern ſide by the northern part of Sobieſki's ſhield, the ſhoulder of Antinous, the head and veſſel of Aquarius, the belly of the weſtern fiſh in piſces; it paſſes through the head of the whale and bright ſtar marked δ in the corner of his mouth, and thence through the ſtar marked δ in the belt of Orion, at that time near the eaſtern ſide of the horizon.

323. *The ecliptic*, that half of it which is then above the horizon, if we begin from the weſtern ſide, preſents to our view capricornus, aquarius, piſces, aries, taurus, gemini, and a part of the conſtellation cancer.

324. The *ſolſtitial colure*, from the weſtern ſide, paſſes through Cerberus and the hand of Hercules, thence by the weſtern ſide of the conſtellation Lyra, and through the dragon's head and body, through the pole point under the polar ſtar, to the eaſt of Auriga, through the ſtar marked η in the foot of Caſtor, and through the hand and elbow of Orion.

325. *The northern polar circle*, from that part of the meridian under the elevated pole, advancing towards the weſt, paſſes through the ſhoulder of the great bear, thence a little to the north of the ſtar marked α in the dragon's tail, the great knot of the dragon, the middle of the body of Cepheus, the northern part of Caſſiopea and baſe of her throne, through camelopardalus and the head of the great bear.

326. *The tropic of cancer*, from the weſtern edge of the horizon, paſſes under the arm of Hercules, under the Vulture, but through the gooſe and fox, which is under the beak and wing of the ſwan, under the ſtar called Sheat marked β in Pegaſus, under the head of Andromeda, and through the ſtar marked φ in the fiſh of the conſtellation piſces,

above the bright ſtar in the head of the ram marked α, through the Pleiades, between the horns of the bull, and through a group of ſtars at the foot of Caſtor, thence above a ſtar marked δ between Caſtor and Pollux, and ſo through a part of the conſtellation cancer, where it diſappears by paſſing under the eaſtern part of the horizon.

327. *The tropic of capricorn*, from the weſtern ſide of the horizon, paſſes through the belly and under the tail of capricorn, thence under Aquarius, through a ſtar in Eridanus marked c, thence under the belly of the whale, through the baſe of the chemical furnace, whence it goes under the hare at the feet of Orion, being there depreſſed under the horizon.

The ſouthern polar circle is inviſible to the inhabitants of London, by being under our horizon.

To

To find the time of the ſun's entry into the firſt point of libra or aries; and thence that point in the equator to which the ſun is vertical at either of thoſe times.

331. This requires the knowledge of a meridian that ſhall paſs through that point in the equator, to which the ſun is vertical at the times of equinox; but as this point is variable, a fixed meridian muſt be firſt obtained.

332. In Anno Domini 1753, the late Rev. Dr. Bradley obſerved the ſun to enter libra September 22d. 10 h. 24 min. afternoon, new ſtile, at the Royal Obſervatory at Greenwich.

333. As the earth's diurnal motion is from weſt to eaſt, it cauſes all places to the eaſt of any other place to paſs firſt under the ſun; therefore when the meridian of Greenwich paſſed under the ſun that day, he was not then arrived at the interſecting point of the earth's equator and celeſtial

ecliptic, but wanted 10 h. 24 min. which is equal to 156 degrees.

334. Whence the fixed or firſt meridian ſought is thus obtained, and lies 10 h. 24 min. in time, or 156 equatorial degrees weſt of the Royal Obſervatory at Greenwich.

335. This meridian is marked by a dotted line on our new terreſtrial globe, it paſſes through the great Pacific Sea, and croſſes one of the Iſles of St. Bernard and the Iſle des Mouches.

The next thing to be conſidered is the neareſt mean length of a tropical year, which is a determinate ſpace or interval of time between one equinox and another, be it either vernal or autumnal.

336. We take for our radix the autumnal equinox, anno 706 of the Julian period, which we call anno mundi 0, and compute from Thurſday Oct. 25th, 0 h. 0 min. or noon, the ſun being then ſuppoſed to be in the firſt point of libra on the meridian before mentioned, and vertical to that point of the equator which lies 156 degrees weſt of Greenwich.

And alſo in the meridian of Greenwich, Oct. 25th. 10 h. 24 m. upon the 298th day from the calends of January.

337. The tropical year thus reckoned exceeds the Egyptian year 5 h. 49 min. and is but 11 minutes ſhort of the Julian year; ſo much being annually allowed for the retroceſſion of the equinox, conſequently the mean length of a tropical year is 365 d. 5 h. 49 min.

338. We are induced to meaſure time by this quantity, becauſe aſtronomers unanimouſly agree, that the earth paſſes through all the ſigns of the ecliptic, ſo as to complete the circle in 365 d. 5 h. 49 min.

339. See the reſpective tables of Rudolphus, Tycho Brahe, Caſſini, Sir Jonas More, Mr. Flamſted, Dr. Halley, Mr. Meyer, and Mr. Maſkelyne; whereby it will appear that,

	S	°	′	″
The ſun's mean motion in 365 days is	11	29	45	40
in 6 hours			14	47
	0	0	0	27
Subſtract, for retroceſſion, the ſun's mean motion in 11 minutes of time				27
	0	0	0	0

	d.	h.	m.
The quantity of one Julian year is	365	6	0
from which ſubſtract the retroceſſion			11
Therefore the remainder	365	5	49

completes the circle, and not one ſecond minute of time more or leſs can be produced from any tables extant.

340. And the difference between calculating downwards from the epoch A. J. P. 706, and calculating backwards in the modern practice from the various epochs in the moſt celebrated tables is, that in thoſe laſt epochs the 11 minutes of retroceſſion have not been conſidered.

	d.	h.	min.
341. From the vernal to the autumnal equinox	186	11	51
From the autumnal to the vernal equinox	178	17	58
	365	5	49

342. The equinoxes regularly fall every year 5 h. 49 min. later in the day, than in the preceding year, and at the end of every annual motion of the earth the equinoctial interſection changes its meridian weſtward of that in which it fell the year before, juſt 87 deg. 15 min.

Precepts for the uſe of the tables of retroceſſion and autumnal equinoxes.

343. Firſt, Find the number of years from the radix, viz. If the given year is before the Chriſtian Æra ſubſtract it from 4008, the remainder is the year from the radix.

344. Secondly, If any year ſince the Chriſtian Æra be given, add it to 4007, their ſum is the year from the radix.

345. Thirdly, Collect the days, hours, and minutes of retroceſſion, and autumnal equinoxes from the table, according to the number of years from the radix, in thouſands, hundreds, tens, and units; add theſe into two ſums, the firſt will be the retroceſſion, the ſecond the time of the equinox, in that meridian which lies 156 degrees weſt of Greenwich Obſervatory; to which add 10 h. 24 m. and you obtain the time at Greenwich.

346. And for any other meridian alſo, if you add its difference in time from the fixed meridian.

347. Solar tropical years thus reckoned begin and end at the autumnal equinox, and all Julian years begin and end at the kalends of January *.

348. In comparing ſolar tropical years with Julian years, by which we ſtill compute time, obſerve, that the laſt nine months of any ſolar tropical year, anſwer to the firſt nine months of that Julian year with which it is compared; and that the firſt three

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* The kalends of January begin from the noon of the preceding day; that is, from the noon of the day before the firſt day of January.

months of the next ſucceeding tropical year anſwer to the three laſt months of that ſame Julian year with which it is compared.

349. The 298th day from the kalends of January, which was Thurſday in the 706th year of the Julian period the ſun entered libra at noon; at which inſtant it was 10 h. 24 min. paſt noon at Greenwich.

350. In all calculations of autumnal equinoxes we take the ſame 298th day, or October 25th in the radical year 0, for our epoch.

351. And to gain the day of the month in which the equinox muſt happen ſince the radix,

Add the number of days, hours, and minutes in the retroceſſion, to the days, hours, and minutes of the equinox in the fixed meridian, and you obtain the Julian days and hours from the radix.

352. Add the epoch 298 to the days of the tropical reduction, and from their ſum ſubſtract the intire days of the Julian reduction, the remainder is the number of days from the kalends of January old ſtile; add thereto eleven days, and you obtain the number of days from the ſaid kalends of

January new ſtile, from which if you deduct the neareſt leſs number in the table of months (which numbers expreſs the laſt days of each month) the reſidue is the day of the ſucceeding month.

353. But when the ſum of the Julian reduction contains eighteen hours above entire days, it is a biſſextile year; then one day more muſt be added to the entire Julian days before the ſubſtraction is made.

354. When there are no hours in the Julian reduction, that year is the firſt after a biſſextile; if ſix hours, the ſecond; if twelve hours, the third; and when eighteen hours above entire days, it is the biſſextile year.

355. To gain the time of the equinox on any other meridian, add the difference of meridians to the time found in the firſt meridian. Thus for London or Greenwich we add 10 h. 24 min. for Paris 10 h. 33 min. 20 ſec. for Alexandria in Egypt 12 h. 25 min. &c.

To gain the week-day.

356. Divide the days of the tropical reduction by 7; if 0 remains, it is Thurſday;

if 1, Friday; 2, Saturday; and 3, Sunday; and ſo on to 6, which is Wedneſday, as in the table of week-days.

To obtain the time of the vernal equinox.

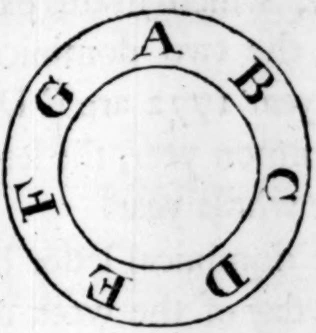
357. Firſt find the autumnal equinox for the ſame year in which the vernal equinox is required; and from it ſubſtract 186 d. 11 h. 51 min. which is the diſtance in time from aries to libra; their difference will be the time of the vernal equinox required.

358. The day of the month and week-day found as above, we obtain the literal character for that day as follows.

In the table of months ſtand the literal characters, that are placed againſt the firſt day of each month in any common almanack.

And whatever letter ſtands againſt the firſt day of any month, the 8th, 15th, 22d, and 29th days of that month are all characteriſed with the ſame.

359. A circle of the 7 literal or week-day characters.



The day of the month and week-day given, to find its literal character and dominical letter for that year.

360. A. D. 1772, the autumnal equinox will happen at Greenwich, September 22d, 0 h. 55 min. on a Tueſday.

QUERE, The literal character for that day and dominical letters for that year, it being biſſextile?

The literal character for the 1ſt of September is F, ſo alſo is the 22d, and Tueſday in the preſent queſtion. Look on the circle of week-day characters, call F Tueſday, G Wedneſday, A Thurſday, and ſo on to Sunday which falls upon D, the laſt of the two dominical letters for that year, and ſerves from the intercalary day to the year's end.

The firſt dominical letter for leap-years is the next in the circle, and ſerves for January and February, which in this example is E.

Therefore the two dominical letters for the biſſextile year 1772 are E D new ſtile.

In any common year, the letter firſt found ſerves for the whole year.

361. The dominical letter being known, to find what day of the week any day in the year falls on.

QUERE, What day of the week is the 20th day of March A. D. 1772?

The literal character for the 1ſt of March is D, ſo is the 15th, and the 20th being 5 days more, if we count from D, which happens to be the dominical letter, to E Monday the 16th, we ſhall find B is Friday the 20th day of March, A. D. 1772 new ſtile.

362. If the dominical letters were required for old ſtile, in theſe examples the firſt would be the 11th of September 1772, whoſe literal character is thus found, F the 1ſt day of September, and alſo the 8th, G the 9th, A the 10th, and B the 11th, and by the following calculus Tueſday, therefore A C are the dominical letters old ſtile, A. D. 1772.

363. Required the autumnal equinox at Alexandria in Egypt, in the 146th year before the Chriſtian Æra.

4008
— 146

A M. 3862 or years from the radix, Oct. 25, A. J. P. 706.

	Retroceſſion.			Tropical reduction.		
years à radix.	d.	h.	min.	days à radix.	h.	min.
3000	22	22	0	1095727	2	0
800	6	2	40	292193	21	20
60	0	11	0	21914	13	0
2	0	0	22	730	11	38
	29	12	2	7)1410565	23	58

weeks 201509+2 Saturday.

Tropical days	565
epoch +	298
	863
Julian days —	595
	268
for Auguſt —	243
♎ Sept.	25

	d.	h.	min.
tropical time	1410565	23	58
retroceſſion +	29	12	2
Julian reduction	1410595	12	0

the 3d year after biſſextile.

	d.	h.	min.	
à kal. Jan.	268	23	58	fixed meridian.
meridian diſk	+	12	25	
the ſun in the firſt point of libra Sept. 26,	269	12	23	at Alexandria.

On a Sunday, dominical letter B, in the 146th year before the Chriſtian Æra.

364. To find the time of the vernal equinox in the ſame year, and at the ſame place.

	d.	h.	min.
From the autumnal equinox, Sept. 26, à kal. Jan.	296	12	23
ſubſtract the diſtance in time between ♈ and ♎	186	11	51
	83	0	32
for February	59		
the ſun in the 1ſt point of aries at Alexandria ante Chriſt 146 years, March	24	0	32

Note, According to the civil reckoning of the hours from midnight, this vernal equinox fell upon the 23d day of March, at 32 minutes paſt noon at Alexandria.

365. To find the time of the autumnal equinox at Greenwich, A. D. 1768.

4007
+1768

A.M. 5775 or years from the radix,

	Retroceſſion.			Tropical reduction.		
years à radix.	d.	h.	min.	days à radix.	h.	min.
5000	38	4	40	1826211	19	20
700	5	8	20	255669	15	40
70	0	12	50	25566	23	10
5	0	0	55	1826	5	5
	44	2	45	7)2109274	15	15
				weeks 301328+6	Wedneſday.	

Tropical

Tropical days	274	tropical time	2109274	15	15
epoch +	298	retroceſſion +	44	2	45
	572		2109318	18	0
Jul. days + 1 —	319	becauſe of the 18 h.	biſſextile year.		
	253	à kal. Jan. old ſtile			
for new ſtile +	11	days			
	264	à kal. Jan. new ſtile			
for Auguſt —	243				
☉ in ♎ Sept.	21		d.	h.	min.
		in the fixed meridian à kal. Jan.	264	15	15
		meridian diſt. +	0	10	24
the ſun in the 1ſt point of libra at Greenwich, Sept. 22,			265	1	39

366. To find the time of the vernal equinox, A. D. 1768.

	d.	h.	min.
From the autumnal equinox, Sept. 22,	265	1	39
ſubſtract diſt. ♈ a ♎	186	11	51
	78	13	48
for Feb.	59	0	0
the ſun in aries at Greenwich, A.D. 1768, Mar.	19	13	48

367. Having found the autumnal and vernal equinoxes for the biſſextile year, A. D. 1768, we obtain them for the three following years by continually adding thereto 5 h. 49 min. thus

☉ in ♈	d.	h.	min.		☉ in ♎	d.	h.	m.
1768, March 19,	78	13	48	-	1768, Sept. 22,	265	1	39
	+	5	49			+	5	49
1769, Mar. 19,	78	19	37	-	1769, Sept. 22,	265	7	28
	+	5	49			+	5	49
1770, Mar. 20,	79	1	26	-	1770, Sept. 22,	265	13	17
	+	5	49			+	5	49
1771, Mar. 20,	79	7	15	-	1771, Sept. 22,	265	19	6

368. Required the time of the autumnal equinox at Greenwich, A. D. 1772.

4007
1772

A.D. 5779 or years from the radix.

	Retroceſſion.			Tropical reduction.		
years à radix.	d.	h.	min.	days à radix	h.	min.
5000	38	4	40	1826211	19	20
700	5	8	20	255669	15	40
70	0	12	50	25566	23	10
9	0	1	39	3287	4	21
	44	3	29	7)2110735	14	31
				weeks 301533+4 Monday.		

Tropical

Tropical days	735	to the tropical time	2110735	14	31
epoch +	298	retroceſſion +	44	3	29
	1033		2110779	18	0
Jul. days + 1 --	780	becauſe of the 18 h.	biſſextile year.		
	253	à kal. Jan. old ſtile			
for new ſtile +	11	days			
	264	à kal. Jan. new ſtile			
for Auguſt —	243				
⊙ in libra Sept.	21		d.	h.	min.
		in the fixed meridian à kal. Jan.	264	14	31
		meridian diſt. +	0	10	24
the ſun in the firſt point of libra at Greenwich, Sept. 22.			265	0	55

On a Tueſday, dominical letters.

369. To obtain the vernal equinox, A. D. 1772.

	d.	h.	min.
From the autumnal equinox, Sept. 22, à kal. Jan.	265	0	55
diſt. from aries to libra	186	11	51
	78	13	4
for February	59		
the ſun in the 1ſt point of aries at Greenw. Mar.	19	13	4

370. We find the two equinoxes in the three next ſucceeding common years, as in the preceding example, by the continual addition of 5 hours, 49 minutes.

By this method of calculation, we avoid any miſtake that might happen with reſpect to the intercalary day; becauſe we find the autumnal equinox firſt, and thence the vernal equinox, which always falls after the intercalary day, and alſo as tropical time has no biſſextile years.

To reduce hours, minutes, and ſeconds of time, into degrees, minutes, and ſeconds of the equator.

371. Divide the ſeconds of time by 4, the quotient is minutes, and remainder ſo many times 15 ſeconds.

Divide the minutes by 4, the quotient is degrees, and remainder ſo many times 15 minutes.

Multiply the hours by 15, the product is degrees.

EXAMPLE.

Reduce 11 h. 35 min. 27 ſec. of time into degrees, minutes, &c. of the equator.

ſec.	min.	h.		deg.	min.	ſec.
4)27	4)35	11		165	0	0
—	—	15		8	45	0
6′ 45″	8° 45′	—		0	6	45
		165°		—	—	—
			anſwer	173	51	45

To reduce degrees, minutes, and ſeconds of the equator, into hours, minutes, and ſeconds of time.

372. Divide ſeconds by 15, the quotient is ſeconds, and remainder ſo many times 4 thirds.

Divide minutes by 15, the quotient is minutes, and remainder ſo many times 4 ſeconds.

Divide the degrees by 15, the quotient is hours, and remainder ſo many times 4 minutes.

EXAMPLE.

EXAMPLE.

Reduce 173 deg. 51 min. 45 ſec. of the equator, into hours, minutes and ſeconds of time.

ſec.	min.	deg. h.	h.	min.	ſec.
15)45(3″	15)51(3′	15)173(11	11	32	0
45	45	15	0	3	24
—	—	—	0	0	3
0	6=24″	23			
		15	11	35	27 anſwer.
		—			
		8=32′			

We are now prepared to ſolve the latter part of the laſt problem, which is as follows.

PROBLEM XLV.

To find all thoſe places where it is noon at the time of an equinox, as well as that point upon the equator, to which the ſun is vertical at that time.

Having found the time of an equinox by the preceding or any other method of calculation, as in the firſt example; we find the ſun entered the firſt point of aries at Alexandria in Egypt, March 24th, 0 h. 32 min. which was March 23d. at 32 minutes paſt noon.

The 32 minutes of time reduced to the equator, are equal to 8 degrees.

Therefore bring Alexandria under the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII upon the equator, turn the globe from weſt to eaſt until 32 minutes of time, or 8 degrees of the equator have paſſed under the horary index, where ſtop the globe; then all thoſe places under the ſaid graduated ſide of the ſtrong braſs meridian will have noon, and that degree of the equator, which is then under the meridian, is the point to which the ſun was at that inſtant vertical, and is the interſecting point of the equator and ecliptic, or that terreſtrial meridian which governs the paſſage of the firſt point of aries for that year.

The vernal equinox, A. D. 1772, will fall on the 19th day of March, at 13 h. 4 min. which reduced to the degrees and minutes of the equator, is equal to 196 degrees.

374. Bring London to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII, (in this caſe the graduated ſide is the horary index) turn the globe from weſt to eaſt until 13 h. 4 min. of time, or 196 degrees of the equator have paſſed under the horary index, where ſtop the globe; the 196th degree of the equator will now be found under the graduated ſide of the braſs meridian, and is that point on which the ſun will be vertical at noon; at which inſtant it will be 13 h. 4 min. paſt noon at London or Greenwich.

The meridian paſſing through this point, will be ſeen to paſs a little eaſtward of Kamkatſki, through the Pacific Sea, acroſs the iſland Dicerta, thence eaſt of the iſle Taumago, and through the weſtern part of

New Zeland, all which places will have noon at the inſtant of that vernal equinox.

The autumnal equinox, A. D. 1772, will happen September 22d, 0 h. 55 min. at London, the 55 min. being equal to 13 deg. 45 min. of the equator.

375. Bring London to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII, turn the globe from weſt to eaſt, until 55 minutes of time, or 13 deg. 45 min. of the equator have paſſed under the horary index, where ſtop the globe; here, as in the laſt example, the 13th degree and 45th minute is that point upon the equator to which the ſun is vertical, and the meridian paſſing through this point, lies under the graduated ſide of the ſtrong braſs meridian; which paſſes over the middle of Greenland, and through the Atlantic Ocean to the eaſt of Teneriffe, a little to the weſt of Aſcenſion Iſland, and thence through the Ethiopic Ocean, at which places it will

be noon at the time of this autumnal equinox.

Here it will be proper to give the reader a ſhort account

Of the natural agreement between the celeſtial and terreſtrial ſpheres; or, How to gain a perfect idea of the ſituation and diſtance of all places upon the earth, by the ſun and ſtars.

376. That part of the firmament which is in the zenith of London, is perpendicular to half the globe of the earth; which half comprehends almoſt all the habitable land of Europe, Aſia, Africa, and America, with their coaſts, capes, land and ſeas; ſince under the other celeſtial hemiſphere, which we do not ſee at the ſame time, there are only very inconſiderable lands and iſles.

377. The inhabitants of Great Britain and Ireland nearly ſee the ſame half of the firmament adorned with ſtars and planets, which at all times ſupply the place of an

immenſe map of the world; and ſhew our terreſtrial hemiſphere by the ſtars, conveying the correſpondent marks of the two continents to our ſight and mind.

378. The ſun, by his apparent daily motion, ſeems to deſcribe a kind of ſpiral, in paſſing from one tropic to the other and back again, continually changing his declination, and every day deſcribing a different parallel, art. 104.

Forty-ſeven of theſe diurnal parallels are drawn on our new terreſtrial globe, art. 115. 116. between the tropics of cancer and capricorn, repreſenting the parallels for every degree of the ſun's declination.

379. Before the reader proceeds, he is deſired to make himſelf acquainted with the cauſe of the daily change in the ſun's declination, beginning at article 150, and reading from thence to the 166th article.

Which being premiſed, it will be eaſy to conceive, that the ſun being in any one of theſe parallels, muſt neceſſarily caſt his perpendicular rays that day upon the heads of the inhabitants of thoſe places through which that parallel of declination paſſes.

Note, Although theſe 47 parallels are here called parallels of declination, they are alſo parallels of latitude upon the terreſtrial globe.

380. From theſe principles we obtain the ſituation of thoſe places, to which the ſun is vertical every day in the year; we alſo find the time of that day at the place of any obſerver, from whence looking at the ſun, we may pronounce him to be over the heads of the inhabitants of divers cities and ſtates, during the ſeveral hours of that day, and ſo on for every day in the year.

381. The ſun being perpendicularly over any one of theſe diſtant cities or principalities, at the time of our obſervation, if a plumb-line be held up between the obſerver and the ſun, ſo as to paſs through or before the ſun's center, it will cut the viſible horizon in a point, that will fix the bearing or paſſage in a right line from the obſerver to that place, upon which the ſun is then vertical.

382. A point thus noted upon the viſible horizon, may be ſeen at all times, and repreſent the ſame bearing, independent of the ſun and ſtars, and that in ſuch a conſpicuous

manner as to render this knowledge always entertaining, uſeful and intereſting.

383. The ſtars at night perform the ſame more copiouſly, by pointing out to our ſenſes the diſtance of many diſtant provinces, at one and the ſame inſtant of time, from our own zenith.

Hence we are in poſſeſſion of a moſt immenſe and extenſive field, wherein we may correct and improve our aſtronomical and geographical knowledge.

Examples of ſolar correſpondents.

PROBLEM XLVI.

To find the ſolar correſpondence to a fixed point upon the earth, when the ſun is ſeen by an obſerver, ſituated upon any other point of its ſurface.

EXAMPLE I.

384. Let the obſerver be in London (or in any of the country places within thirty

miles of it) upon the 10th day of March, at 10 minutes paſt XI o'clock in the morning.

QUERE, The place upon which the ſun will be vertical at that time?

Rectify the globe by bringing the 10th of March, engraved on the backſide of the ſtrong braſs meridian, to the plane of the broad-paper circle; find the ſun's place, againſt the day of the month in the kalendar, which will be about 20 deg. 10 min. in piſces; ſeek theſe degrees and minutes in the ſign piſces upon the ecliptic line on the globe, and you will find it fall upon the fourth parallel of ſouth declination, to all the inhabitants on this parallel the ſun will be vertical that day. Now bring 11 h. 10 min. on the equator to the graduated ſide of the ſtrong braſs meridian, and you will find it cut the fourth ſouthern parallel upon the city of Loango, on the weſtern coaſt of Africa.

Therefore if you look at the ſun 10 minutes paſt XI in the morning at London, you will then ſee him at the inſtant he is directly over the heads of the inhabitants of the city of Loango in Africa; at the ſame time, your ideas are made ſenſible of the comparative diſtance, which you ſee in the firmament between the zenith of London under which you ſtand, and the ſun, which is then in the zenith of Loango; alſo if at the time of your obſervation, you cauſe a plumb-line to be held up between you and the center of the ſun, and caſt your eye down towards the moſt diſtant part of your ſenſible horizon, the plumb-line will cut a point thereon, which, if remembered, will always ſhew you the true bearing or point of the compaſs, in a direct line from your ſituation, to that of Loango.

385. This diſtance and bearing may be nearly found by the globe; thus,

Elevate the globe to the latitude of London, that the broad-paper circle may repreſent your horizon, ſcrew the nut of the quadrant of altitude in the zenith, that is upon 51 deg. 32 min. counted from the equator towards the elevated pole, bring London under that point, and lay the graduated edge of the quadrant upon Loango, which will cut the bearing 15 degrees, reckoned from the ſouth towards the eaſt, or between the points S S E and S b E; now ſeparate the quadrant from the globe, and lay its graduated edge upon Loango and London, ſo that the beginning of the graduation may lie upon one of the places, then the other will cut 56 degrees, which is equal to 3360 geographical miles, or 3892 Engliſh miles, the diſtance between London and Loango.

386. To elucidate this example, we ſhall trace the ſun's verticity over that part of this day's parallel of declination, as is included between the riſing and ſetting ſun at London for that day.

Imagine, as we have before ſuppoſed, an image of the ſun to be painted upon the cieling of the room, directly over the terreſtrial globe.

Let the globe be rectified to the 10th of March, place the center of the artificial horizon upon London, and bring it into a coincidence on the weſt ſide of the plane of the broad-paper circle, now repreſenting the edge of the earth's illuminated diſk; we ſhall then have the poſition of the earth with reſpect to the ſun for that day; when the inhabitants of London will be leaving the twilight, and paſſing into the firſt point of day, or ſun-riſing, at about 18 minutes paſt VI in the morning, cut by the graduated ſide of the ſtrong braſs meridian on the hour line under the equator; at this time the meridian will likewiſe croſs the fourth parallel of ſouth declination, in the Indian Ocean, between the iſland of Sumatra and the Maldive Iſles; if we look upon the ſun that morning at the inſtant of his riſing, we ſhall ſee that his diſtance from our zenith will then be 90 degrees, he being in our horizon, which is equal to 5400 geographical or 6155 Engliſh miles, the diſtance from London to that part of the Indian Sea; turn the globe from weſt to eaſt, until 8 h. 12 min. are under the horary index, which in this caſe is the ſtrong braſs meridian, and it will cut the iſle Macarenhas, to which the ſun will then be perpendicular, at ½ paſt IX he will be perpendicular to the coaſt of Zanguebar, his central ray paſſing between Monibacca and Pemba, thence it paſſes over the kingdoms of Monomugi, Macoco, Congo, &c. until he is perpendicular to the city of Loango, upon the weſtern coaſt of Africa, at 11 h. 10 min. the ſame morning; immediately after which his perpendicular rays are abſorbed in the Ethiopic Ocean, over which he is 3 h. 22 min. in paſſing to Fort St. Lucar, on the eaſtern coaſt of America, at 32 minutes paſt II in the afternoon; thence he proceeds to ſend forth his perpendicular rays over the heads of the inhabitants of Brazil, acroſs the vaſt country of the Amazons and Peru, in the decline of our evening, until his arrival over Cape Blanco on the weſtern ſide of South America, a little before he ſets to the inhabitants of London, which is about 40 minutes paſt V o'clock.

EXAMPLE II.

387. Every rectification being obſerved as in the firſt example, required the place upon which the ſun is a correſpondent at 48 minutes paſt VI in the evening of the 18th of May, the ſun's place being about 17 deg. 40 min. in taurus, which ſhews upon the globe, that the ſun will be nearly vertical to the 17th parallel of north declination on that day. Turn the globe from weſt to eaſt, until London has paſſed the ſtrong braſs meridian and ſtop, when its

graduated ſide is directly over 6 h. 48 min. afternoon, and it will cut upon the 17th parallel of north declination, the city of Acquapulco on the weſtern coaſt of Mexico, over which the ſun will then be vertical.

EXAMPLE III.

388. Let the obſerver be at Cape Clear on the weſtern coaſt of Ireland, on the 16th day of July, at 54 minutes paſt VIII in the morning.

QUERE, The place upon which the ſun will then be vertical?

The ſun's place being in the 24th degree of cancer, which on the globe falls upon the 21ſt parallel of north declination.

Bring Cape Clear to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII, turn the globe till 8 h. 54 min. amongſt the morning hours are under the horary index, and you will find the graduated ſide of the ſtrong braſs meridian to cut the 21ſt parallel of north declination upon Farrat in Nubia, on the weſtern coaſt of the Red Sea.

EXAMPLE IV.

389. Let the obſerver be at Rome, on the 20th day of November, at 37 minutes paſt X in the morning.

QUERE, The place upon which the ſun will be vertical at that time?

The ſun being about 28½ degrees in ſcorpio, which falls to the ſouthward of the 20th parallel of ſouth declination.

Bring Rome to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII, turn the globe to have 10 h. 37 min. under the horary index, and the ſaid graduated ſide will then cut under the 20th parallel of ſouth declination the city of Sofala in the kingdom of Quiteri, to the ſouth of Monomotapa, on the eaſtern coaſt of Africa.

We apprehend theſe four examples are ſufficient to give the reader a clear idea of the ſolar correſpondents to all places within the torrid zone, and to enable him to diſcover ſome thouſands more.

390. Although we can have but one ſolar correſpondent at the ſame time, yet as in the firſt example, we can trace him through

his diurnal parallel for every hour and minute of the day, and ſo alſo upon every day in the year.

391. Nothing can be eaſier or more intelligible than this method of improving the mind by repreſenting to the eyes the diſtance from our own zenith to the zenith of every ſpot of land and ſea, within the tropics; when at every ſingle obſervation we have it alſo in our power to note the bearing of each of theſe places upon our viſible horizon, which may be referred to, at all times, when the ſun is not in that parallel.

392. Let us now change the ſcene from that of the great globe of day, to obſerve the ſtars by night, which will preſent to our view a copious field of geographical knowledge; many of which may be ſeen at one and the ſame inſtant of time, when they are in the zenith of ſo many different places upon the earth, and then immediately afterwards remove from that deſignation, to give place for a great number of others.

Of the celeſtial correſpondents.

393. The knowledge of the celeſtial correſpondents diſcover a new ſyſtem of aſtronomical geography, an object worthy of attention. The perfect agreement between the celeſtial and terreſtrial ſpheres being an aſſemblage of both, and it may with very little trouble be attained, in making the ſtudy of one a means to arrive at the other; the object of this correſpondence being the continual variation between the parts of the celeſtial and terreſtrial ſpheres.

394. Geography alone being eaſier than aſtronomy, has generally a particular place in the education of young ſtudents, who ſeldom leave their juvenile ſtudies without gaining ſome idea of the four quarters of the world, a ſlight notion of the ſituation of places with reſpect to each other, and a ſketch of the principal empires; but generally without any application to the terreſtrial, and ſcarce ever a compariſon of that and the celeſtial globe, and without feeling a lively curioſity of knowing theſe neceſſary

and improving branches of the ſcience of hiſtory and its peculiar events.

395. To facilitate the ſtudy of geography, it has always been neceſſary to lay maps and charts before a pupil, which are generally ſeparate plans of different countries. But what idea do theſe afford of the vaſt extent of the earth, of its ſpherical form, or of the proportionable diſtances, real bearings, &c. of the empires, kingdoms, and ſtates on the habitable part of our terreſtrial globe?

396. How much more intelligible and juſt are the proportionable diſtances of the fixed ſtars, when compared with the natural diſtances of the ſeveral places upon the earth, over which they dart their perpendicular rays; thereby conſtituting this new ſyſtem of aſtronomical geography, by ocular demonſtration. They are faithful teſtimonies of the vaſt extent of the univerſe, and they declare the diſtance, bearing, and ſituation of all places upon the earth.

397. By theſe means, together with the aſſiſtance of maps and charts, ſuch a copious and clear idea of geography will be attained, and its natural principles ſo firmly eſtabliſhed, as never to be eraſed.

398. The conſequences to be drawn from theſe principles, are entirely in favour of the harmony between the celeſtial and terreſtrial ſpheres.

Of the paſſage or tranſit of the firſt point of aries over the meridian.

399. This point determines the apparent daily motion of the heavens, and fixes the continual differences in the courſe of the ſun and ſtars.

It is by the knowledge of that peculiar point on the terreſtrial equator, where its interſection with the celeſtial ecliptic happens to fall at the time of a vernal equinox, it is that place upon the earth to which the ſun is vertical at that time; and from the knowledge of this we obtain the time of its paſſage over any meridian upon the globe, for every day of the year.

400. The conformity of the degrees of right aſcenſion, with thoſe of terreſtrial longitude, happen but upon one moment of the 24 hours, in a natural day, when the firſt point of aries is on the meridian of London, the firſt degree of right aſcenſion is on this

meridian alſo; and the ſignal to confirm this is, when a ſtar of the ſecond magnitude marked γ near the extremity of the wing of Pegaſus, is upon the meridian, at that inſtant the equinoctial colure will be upon the meridian alſo, for this colure paſſes through the firſt point of aries and that ſtar.

401. This is the moment when each of the 360 degrees of right aſcenſion in the celeſtial ſphere, is perpendicular to every like degree of terreſtrial longitude; at which time there is a perfect parallelism and perpendicular correſpondence of all the circles, points, and lines, in both ſpheres.

402. To this we have paid a particular regard, in the conſtruction of our new globes, by numbering the degrees on the equator of the terreſtrial globe, with an upper row of figures in the ſame direction, as thoſe of right aſcenſion are numbered upon the celeſtial globe.

403. If from that inſtant of time, when the ſtar γ of pegaſus is upon the meridian, we conceive the ſtars to be immoveable, and that we, together with the globe of the earth, are turned from weſt to eaſt upon the

equatorial axis, we ſhall perceive our own meridian, to paſs ſucceſſively under every degree and ſtar on the celeſtial equator.

404. And that the reader may thoroughly underſtand what is meant by this uniformity in the two ſpheres, let him imagine the celeſtial globe to be delineated upon glaſs or any other tranſparent matter, which ſhall inveſt or ſurround the terreſtrial globe, but in ſuch a manner, that either may be turned about upon the poles of the world, whilſt the other remains fixed; and ſuppoſe the firſt point of aries, on the inveſting globe, to be placed upon the firſt point of aries on the terreſtrial globe, (which point is in the meridian of London,) they will then repreſent that ſituation of the heavens and the earth, we have been juſt deſcribing, on that inſtant, when the firſt point of aries is upon the meridian; and then every ſtar on the celeſtial will lie upon every particular place of the terreſtrial globe, to which it is a correſpondent; each ſtar will then have the degree of its right aſcenſion directly upon the corresponding degree of terreſtrial longitude; their declination will

alſo be the ſame with the latitude of thoſe places upon which they lie.

405. Now if the reader conceives the celeſtial inveſting globe to be fixed, and the terreſtrial globe to be gradually turned from weſt to eaſt, he will readily underſtand, as the meridian of London paſſes from one degree to another under the inveſting ſphere, that every ſtar thereon becomes a correſpondent to another place upon the earth; and ſo on until the earth has completed one diurnal revolution, or till all the ſtars, by their apparent daily motion, have paſſed over every meridian of the terreſtrial globe. Hence ariſes an immenſe and an amazing variety in the harmony of both ſpheres.

406. If the ſun and a ſtar tranſit the meridian on any particular day, the next day the ſtar will precede the ſun about 4 minutes; in two days the acceleration of the ſtar with reſpect to the ſun will be about 8 minutes, in 4 days 16 minutes, in 8 days 32 minutes, and in fifteen days the apparent motion of the ſtar will be accelerated one hour, whilſt the ſun, with reſpect to the ſtar, will ſeem to be retarded one hour; in one month the ſtar will be two hours before the

ſun, in three months ſix hours, in ſix months twelve hours, and in one year twenty-four hours.

407. So that a year after the ſun and ſtar have croſſed the meridian together, they will meet again nearly at the ſame time; but the ſtar inſtead of ſeeming to make 365 revolutions will have made 366, one more than the earth to the ſun in a year.

408. The right aſcenſion of the firſt point of aries, is the complement of the ſun's right aſcenſion to 360 degrees of the equator, or to the 24 hours of a natural day: this is the point from which the right aſcenſion of the ſun, ſtars, and planets is always reckoned.

409. The reader will pleaſe to obſerve, that in ſpring and ſummer, the firſt degree of right aſcenſion, which is the firſt point of aries, comes to the meridian with us before noon; there are no ſtars then viſible in the night, but thoſe which follow the firſt point of libra; that is to ſay, thoſe ſtars which have more than 180 degrees of right aſcenſion: in autumn and winter thoſe ſtars are viſible in the night, which follow the firſt point of aries, having leſs than 180 degrees of right aſcenſion.

410. Obſerve alſo, that the interval between the paſſage of the firſt point of aries over the meridian of any place, and that of the firſt point of libra over the ſame meridian, is not 12 complete hours, but only 11 hours 58 minutes, to which attention muſt be paid, leaſt theſe two minutes ſhould be miſtaken.

411. By the paſſage of the ſtars over the meridian, we are taught the knowledge of thoſe degrees of the equator, which are then riſing and ſetting; for that degree which is ſetting precedes that on the meridian 90 degrees, or ſix hours; and 180 degrees or twelve hours that which is riſing; and that degree of the equator, which is on the meridian under the elevated pole, is 180 degrees diſtant from that point of it which is paſſing the meridian.

Problem XLVII.

To find the time of the right aſcenſion of the firſt point of aries upon any meridian.

412. We have already ſhewn by an eaſy calculus, how to find the times of equinox to any meridian, but we have not yet ſhewn their application to the right aſcenſion of the firſt point of aries.

413. The diurnal difference of right aſcenſion, at the time of a vernal equinox, is 3 min. 38 ſec. which we have formed into a table, entitled, *The horary difference in the motion of the firſt point of aries at the time of a vernal equinox*; to which is annexed, *a table of the difference of the paſſage of the firſt point of aries over the meridian for every day in the year.*

The uſe of the tables of right aſcenſion.

414. Having found the time of any vernal equinox, and transferred it from the

fixed to your own meridian by the addition of your meridian diſtance.

Take out of the table of horary differences, the motion anſwering to the hours and minutes of the time of the vernal equinox, and their ſum will be the time of the paſſage of the firſt point of aries over that meridian; the day on which, but before the equinoctial interſection happens. Thus,

415. A. D. 1769, the vernal equinox falls on March 19th, 19 h. 37 min.

		min.	ſec.
	hours 19	2	53
	min. 37	0	6
Right aſcenſion of ♈ ☉, upon the equinoctial day		2	59 paſt noon.

416. A. D. 1770, the ſun will enter aries March 20, 1 h. 26 min.

		min.	ſec.
	hours 1	0	9
	min. 26	0	4
Right aſcenſion of ♈ ☉ on the equinoctial day, at		0	13 paſt noon.

417. A. D. 1771, the vernal equinox falls on March 20, 7 h. 15 min.

		min.	ſec.
hours	7	1	4
min.	15	0	2
Right aſcenſion of ♈ ☉ on the equinoxial day, at		1	6 paſt noon.

418. A. D. 1772, the ſun will enter aries, March 19, 13 h. 4 min.

		min.	ſec.
hours	13	1	58
min.	4	0	1
		1	59

419. The right aſcenſion of the firſt point of aries, thus found for the day on which the equinox happens, holds good for the whole year, and is to be added to the difference of the paſſage of the firſt point of aries over the meridian found againſt the day of the month; and their ſum will be the time of day when the firſt point of aries will paſs the meridian.

420. Obſerve when the equinox falls on the 19th day of March in a common year, to ſeek the day of the month in the right hand column of the table; and when it

falls upon the 20th day of March, ſeek the day of the month in the left hand column, over which in either caſe, and under the name of the month, you have the proper difference of right aſcenſion to be added to that found above for the day of the equinox.

421. In biſſextile years, ſeek the day of the month in the left hand column, to the end of February, and for the intercalary day or 29th of February, take out the difference of right aſcenſion anſwering to the firſt of March, after which to the year's end ſeek the day of the month in the right hand column.

422. Having thus found the right aſcenſion of the firſt point of aries for any day in the year, add thereto 11 h. 58 min. and you obtain the time of the right aſcenſion of the firſt point of libra.

EXAMPLE I.

423. A. D. 1769, equinox March 19.

	h.	min.	ſec.
Jan. 25,	3	23	24
+		2	59
Right aſcenſion ♈ ☉,	3	26	23
Nov. 14,	8	36	31
+		2	59
Right aſcenſion ♈ ☉,	8	39	30

EXAMPLE II.

A. D. 1770, equinox March 20.

	h.	min.	ſec.
Feb. 25,	1	24	52
+		0	13
Right aſcenſion ♈ ☉,	1	25	5
Oct, 18,	10	26	6
+		0	13
Right aſcenſion ♈ ☉,	10	26	19

EXAMPLE

EXAMPLE III.

A. D. 1771, equinox March 20.

	h.	min.	ſec,
Jan, 12,	4	22	46
	+	1	6
Right aſcenſion ♈ ☉,	4	23	52
Decem. 16,	6	22	58
	+	1	6
Right aſcenſion ♈ ☉,	6	24	4

EXAMPLE IV.

A. D. 1772, equinox March 19.

Biſſextile year.

	h.	min.	ſec.
Feb. 28,	1	13	35
	+	1	59
Right aſcenſion ♈ ☉,	1	15	34
The intercalary day, Feb. 29,	1	9	50
	+	1	59
Right aſcenſion ♈ ☉,	1	11	49
March 1,	1	6	7
	+	1	59
Right aſcenſion ♈ ☉,	1	8	6
Auguſt 28,	13	28	17
	+	1	59
Right aſcenſion ♈ ☉,	13	30	16

Theſe four examples are quite ſufficient, if the reader compares them with the tables and precepts.

In the 42d and 43d problems, we have ſhewn how to find the hour that any known ſtar comes to the meridian; and alſo to find the time of the year any ſtar paſſes the meridian at any hour propoſed, art. 317, 318. but in that place we were not prepared to apply the right aſcenſion of the firſt point of aries, ſo properly for an obſervation of the ſtars, as by the following

PROBLEM XLVIII.

To find the time of the right aſcenſion of any ſtar, upon any particular meridian, on any day in the year.

424. Firſt find the time of the right aſcenſion of the firſt point of aries, art. 412, by problem 47, agreeable to your own meridian.

Then apply to the celeſtial globe, and bring the given ſtar under the graduated ſide of the ſtrong braſs meridian, which will cut its right aſcenſion, or rather its diſtance in time or degrees, upon the equinoctial; add this quantity expreſſed in time to the right aſcenſion of the firſt point of aries, and you will obtain the time of the paſſage of that ſtar over the meridian very near the truth. Thus,

The ſtar marked γ in the head of draco, will have 268 degrees, or 17 h. 52 min. art. 372. of right aſcenſion or diſtance from the firſt point of aries, which added to the right aſcenſion of that point for the 13th day of July, A. D. 1772, gives the true time of its right aſcenſion that evening, at 10 h. 12 min. this ſtar will be over the heads of the inhabitants of London at that time, its declination being 51 deg. 32 min. equal to the latitude of this capital city.

Note, In this method of working, when the hours exceed 24, deduct 24 hours therefrom, and you obtain the true time ſought.

PROBLEM XLIX.

To rectify the celeſtial globe for any time in the evening of any day in the year, by the knowledge of the time when the firſt point of aries ſhall paſs the meridian that day.

425. As the degrees and hours upon the equinoctial line on our new globes, are numbered from the firſt point of aries.

Firſt find the right aſcenſion of that point by problem 47, art. 412, for the given day, and rectify the globe to your latitude, art. 116, then bring the firſt point of aries upon the globe, under the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to the hour and minute of the paſſage of aries 0, firſt found, turn the globe until the given hour is under the horary index, and place it due north and ſouth by the mariners compaſs, attending to the variation of the needle, and you will have a perfect repreſentation of the ſtarry firmament, not only for that inſtant, but as long as you pleaſe to apply yourſelf to the knowledge of the ſtars that evening, by only moving the globe to any other minute under the horary index as the time advances.

426. Thus on the 25th of February, A. D. 1770, about 26 minutes after V in the evening, the ſtar called al-debaran, or the bull's eye, will be upon the meridian of London, or places adjacent; about VI o'clock that evening, Orion will begin to paſs the meridian, and preſent a glorious view to the eyes of the obſerver, there being ſo many eminent ſtars in that conſtellation, then ſucceſſively paſſing over the meridian until ½ paſt VII; all the ſtars in auriga, or the charioteer, will be paſſing the meridian at the ſame time; after which canis major will ſucceed with ſyrius, the dog-ſtar, at the ſide of his jaw; then canis minor and gemini or the twins will follow, and ſo on for the remainder of the night. This appearance may be obſerved ſeveral months, but at different hours in the night, which may be found by this problem.

427. Alſo on the 8th of May in the ſame year, the firſt point of aries will paſs our

meridian at 20 h. 58 min. 29 ſec. but if we reckon the hours from midnight, at 58 minutes paſt VIII in the morning, at which time no ſtars can be ſeen ; therefore we muſt have recourſe to the right aſcenſion of the firſt point of libra, which is thus obtained,

	h.	min.	ſec.	
To the right aſcenſion of the firſt point of aries	20	58	29	
add	11	58	0	
	32	56	29	
When the hours exceed 24, ſubſtract therefrom	24	0	0	
The right aſcenſion of the firſt point of libra, A. D. 1770, May 8th, at	8	56	29	in the evening.

428. Now in the precept to this problem, read libra inſtead of the word aries, and the rule will hold good in this as well as in the firſt caſe. Therefore,

Bring the firſt point of libra to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to 56 minutes paſt VIII in the evening, turn the globe until the horary index points to 10 minutes paſt X o'clock, and you will find the ſtar called Spica virginis, being that in the ear of corn ſhe holds in her hand, a ſtar of the firſt magnitude marked α, upon the meridian at that time. If you then look at the firmament, you will ſee the conſtellations cancer, leo minor, leo major, the great bear, with the head and wings of virgo, on the weſtern ſide of the meridian; and on the eaſtern ſide thereof, the ballance, ſcorpio, bootes, Hercules, &c. ſucceſſively following the firſt point of libra in their paſſage over the meridian.

The correſpondency of the fixed ſtars.

429. Before we attempt an obſervation of this kind, a ſignal or warning ſtar muſt be firſt obtained; that is, ſuch a ſtar is to be ſought, as ſhall have the ſame or nearly the ſame quantity, either in degrees or time of right aſcenſion, reckoned from the firſt point of aries, as the place, over which any other ſtar ſhall then happen to be a correſpondent, ſhall have of longitude, reckoned eaſtward of London.

430. It has been ſhewn that declination in the celeſtial and latitude on the terreſtrial

globe, mean one and the ſame thing, both being meaſured by their diſtance from the equator; conſequently, if the declination of any ſtar is equal to the latitude of any place, that ſtar, by a line conceived to be drawn from it to the center of the earth, will deſcribe the parallel of that place; whence it becomes a correſpondent, not only to that particular place, but alſo to all thoſe places which lie in the ſame parallel of latitude, by paſſing perpendicularly over the heads of them all once every 24 hours. But as a preparation to this propoſition, we muſt firſt ſhew, by the following problems, how to find thoſe places to which any ſtar is a correſpondent, and thoſe ſtars which are correſpondents to any place.

PROBLEM L.

To find all thoſe places to which any ſtar is a correſpondent.

431. Firſt find the declination of the ſtar on the celeſtial globe by problem V, art. 55. and remember whether it be north or ſouth; count the ſame number of degrees upon

the ſtrong braſs meridian of the terreſtrial globe the ſame way from the equator, and note the place by holding the edge of a card thereto; turn the globe from eaſt to weſt, and all thoſe places which paſs under that point, will be correſpondents to that ſtar, becauſe they will be in the line paſſing from the center of the earth through the very place upon its ſurface, to which the ſtar is at that time vertical. Thus,

The declination of the ſtar marked γ, in the head of draco, is 51 deg. 32 min. equal to the latitude of London; therefore this brilliant ſtar of the ſecond magnitude may be called the ſtar of this metropolis, without being deprived of its own name; it may likewiſe take the name of any other place in the parallel of London.

432. The reverſe of this problem being to find all the ſtars which are correſpondents to any place, is ſo eaſy as to require no farther explication, than that of applying firſt to the terreſtrial globe.

The apparent diurnal motion of one ſtar only, will ſucceſſively ſhew its perpendicularity to various countries, as will appear by

A general

A general deſcription of the paſſage of the ſtar marked γ in the head of the conſtellation draco, over the parallel of London.

433. This eminent ſtar traces the parallel of London, and is a ſtar of perpetual apparition to the inhabitants of the Britannic Iſles; it comes upon the meridian of London with the 268th degree of right aſcenſion, and is at that time directly perpendicular to or over the heads of the people in this city, two minutes of an hour after its warning ſtar marked k in the milky way, has paſſed the meridian.

434. Note, This ſtar marked k is the ſouthermoſt of a group of five ſtars, ſituated between the ſhoulder of ſerpentarius and Sobieſki's ſhield, which in the firmament appear in the form of a Roman V, as may be ſeen upon the globe.

435. The declination of our correſpondent ſtar γ in the head of draco, is 51 deg. 32 min. equal to the latitude of London; with which apply to the terreſtrial globe,

and bring London to the graduated ſide of the ſtrong braſs meridian, and ſet the edge of a card thereto, holding it to the braſs meridian with your right hand, while you gradually turn the globe from weſt to eaſt with the other hand, and that point of the card which is upon the globe will then repreſent the interſection of that line upon the ſurface of the earth, which we have ſuppoſed to paſs from the center of the earth to the ſtar; and as this point, though at reſt, paſſes over the parallel of London upon the globe, ſo does the central ray, proceeding from the ſtar, really paſs over every point of land, and ſea, upon that part of the earth which is circumſcribed by the parallel of London.

436. Thus you will ſee the ſtar marked γ, in the head of draco, paſs from London over the road to Briſtol, and dart his perpendicular rays upon that city; then croſſing the ſea, it reaches Ireland between Kinſale and Cork, and leaving that kingdom, will ſhine over the Atlantic Ocean, until he is perpendicular to the north cape of Newfoundland; whence it will be vertical to Eſkimos, and paſs between lake Achoua and the north-

ern

ern coaſt of the gulph of St. Lawrence, then he will croſs St. James's Bay, Kriſtino, &c. and paſs weſtward over a vaſt ſpace of land but little known to the Europeans; thence will leave the weſtern coaſt of North America, to ſhine upon the northern part of the Pacific Ocean, until he is perpendicular to ſeveral iſlands, one of which is called St. Abraham; it croſſes the ſouthern land of Kamſchatſka, and the iſland Sangalien; thence it becomes perpendicular to the continent, near Telmen on the eaſt ſide of Mongales in Chineſe Tartary, and ſo proceeds to caſt its perpendicular rays over a vaſt country in Aſia, being ſometimes a zenith point to the Chineſe, at other times to the Ruſſian Tartars, and paſſing over Bielgorod, becomes vertical to Muſcovy, Poland, Germany, and Zeland, and ſo croſſes the ſea again to return to its perpendicularity over the city of London: all which is performed by the earth's diurnal motion in ſo ſhort a time as twenty-three hours and fifty-ſix minutes.

437. When a beginner has been thus exerciſed with the general paſſage of two or three principal ſtars over their correſpondent

parallels on different parts of the earth, his ideas will be ſo greatly improved, that maps and charts may then be laid before him with propriety, in order to confirm him in the knowledge of the particular parts of thoſe very parallels of which he has already attained a general idea upon the globe.

PROBLEM LI.

To find a ſignal or warning ſtar, that ſhall be upon or near the meridian of an obſerver, at the time any known ſtar is perpendicular to any place on its correſponding parallel.

438. Bring the given place to the graduated ſide of the ſtrong braſs meridian on the terreſtrial globe, and it will cut the degrees of its longitude, reckoned eaſtward from London, upon the upper row of figures over the equator; then

Apply to the celeſtial globe, and ſet the given ſtar under the graduated ſide of the ſtrong braſs meridian, which will cut the degree of its right aſcenſion on the equinoctial.

If the ſituation of the obſerver is weſt of the given place, ſubſtract the terreſtrial longitude from the right aſcenſion of the ſtar ; if eaſt, add the longitude, and move the celeſtial globe, till the ſum or reſidue thereof is under the graduated ſide of the ſtrong braſs meridian, and then that ſame ſide will be directly over thoſe ſtars which are upon, or have juſt paſſed, or are not quite come up to the obſerver's meridian, at the moment the given ſtar is vertical to the place propoſed; either of which will correctly anſwer the preſent purpoſe, and become the ſignal or warning ſtar; that upon its arrival on the meridian will declare the given ſtar to be vertical to the place aſſigned.

Thus let the obſerver be in or near London, and the bright ſtar in lyra or the harp of the firſt magnitude be given, it is called vega and marked α; this ſtar is a correſpondent to the ſouth weſt cape of the iſland of Sardinia in the Mediterranean.

439. The longitude of this cape from London is 9 degrees, and the right aſcenſion of the ſtar vega is 277 degrees, as London

is weſt of Sardinia; 9 degrees ſubſtracted from 277 degrees, leaves 268 degrees of right aſcenſion, to which the celeſtial globe being ſet, the graduated ſide of the ſtrong braſs meridian will be found directly over the ſtar γ in draco, and alſo over a ſtar of the fourth magnitude in one of the heads of Cerberus. Theſe are eminent ſignals, and both upon the meridian, when at the ſame time the ſtar marked θ, in the knee of Hercules, will have paſſed the meridian about two minutes of an hour, and the ſtar marked P, of the fourth magnitude in the milky way, will want about two minutes of an hour of coming to it.

440. Hence when the ſtar marked γ, in the head of draco, ſends forth its perpendicular rays upon the city of London, the ſtar vega in lyra will alſo be perpendicular to the S W cape of the iſland of Sardinia. At which time an obſerver at London will be ſenſible of the diſtance between the zeniths of the two places, and may note the bearing of Sardinia from London upon his ſenſible horizon, to which he may refer at any time in the day. An obſerver at Sardinia may note the ſame with reſpect to the diſtance and bearing of London from him.

441. To excite ſtudents who have an aſpiring emulation to improve themſelves in this extenſive ſcience of geography and aſtronomy, the principal requiſites whereby they may acquire univerſal knowledge, we ſhall proceed to illuſtrate this ſyſtem of the natural agreement between the celeſtial and terreſtrial ſpheres, by a few intereſting examples.

EXAMPLE I.

442. When the ſtar marked γ in the head of draco, is perpendicular to the city of London, the twelve following ſtars may be ſeen from thence at the ſame time, when they will alſo be perpendicular to as many places upon the earth.

443. The ſignal or warning ſtar is γ in the head of draco, which comes upon the meridian with the 268th degree of right aſcenſion; it will be vertical to the city of London two minutes of time, after the ſtar marked k, in the milky way, near the equinox,

nox, has paſſed the meridian, at which time the twelve following ſtars will be vertical to the places they ſtand againſt.

West of London.

Rig. Aſc.		Decl. and Lat.			W. Lon.
267½	Knee of Hercules	θ	37	Carthagena, Old Spain	0½
267½	Wriſt of Hercules	ι	30½	Frontiers of Morocco and Targua	0½
261	Ras alhagus, Serpentarius	α	12½	Kingdom Kombergrada, Africa	7
198	Spica Virginis	α	10	Peru, South-America.	70
175	Deneb Alaſad, Lyon's tail	β	16	Chapa in Mexico	93
191	Alioth, 1ſt in tail Great Bear	ε	57	Iſle Belchier, Hudſons Bay	77

Eaſt of London.

Rig^{t}. Aſc.		Decl. and Lat.			Eaſt Lon.
277	Viga, in Lyra	α	38½	S. W. Cape, Iſle of Sardinia	9
295	Atair, Eagle's neck	α	8	Frontiers of Benin and Nigriti, Africa	17
290	Swan's beak, Albireo	β	27½	Mid. Levata in Tagua, Africa	22
308	Deneb, Swan's rump	α	44½	Palmyra	40
343	Sheat, in Pegaſus	β	27	Middle of Mogul's Empire	75
309	Swan's So. Wing	ε	33½	Frontiers of Turkey in Aſia, and Deſart Arabia	41

449. The

444. The uſe of a warning ſtar is to point out the true time of the phenomenon, which is to be firſt nearly found by obtaining the time of the right aſcenſion of that ſtar for the evening, on which the obſervation is intended to be made.

This table of correſpondents was formed as follows,

445. The right aſcenſion and declination of the ſtars was found in round numbers upon the celeſtial globe, and written in two columns, incloſing the names of the ſtars; the columns for the names of the correſpondent places being left blank for their inſertion afterwards.

446. Next, as the longitude on our new terreſtrial globes is numbered both ways from the meridian of London, whatever the right aſcenſion of the ſignal ſtar may happen to be, that point of the celeſtial ſphere is likewiſe conſidered to be upon the meridian of London. Therefore,

447. To gain the longitude in the laſt column of the table, if the given ſtars were eaſt of the ſignal, the right aſcenſion of the warning ſtar was ſubſtracted from the right aſcenſion of the given ſtar.

But the weſt longitude was obtained by ſubſtracting the right aſcenſion of the given ſtars from that of the ſignal.

448. The reverſe of this example is to find, what ſtars will be perpendicular to any place upon the earth, a warning ſtar being known, that ſhall be upon the meridian of an obſerver, when the ſtars to be ſought ſhall be vertical to the places aſſigned, which the reader will eaſily perform from what has been already ſaid.

449. When a ſtar is known to be perpendicular to any aſſigned place, its correſpondence to that terreſtrial point may be equally affirmed to all thoſe who can ſee it at that inſtant from any part of the earth, or ſea, they may then happen to be upon.

450. If an obſerver in Palmyra, another in the middle of the Mogul's empire, a third at Levata in Africa, and a fourth at Chapa in Mexico, ſhould look at the ſtar γ, in the head of draco, the moment it is in the zenith of London, they will ſee its correſpondence to that metropolis at one and the ſame inſtant of time; their hour only will be different according to the difference of meridians, as thoſe places are ſituated either eaſt or weſt from London.

451. The ſignal or warning ſtar to each of theſe places, is the perpendicularity of that ſtar expreſſed in the preceding catalogue of twelve ſtars.

452. From the obſervation under either of theſe ſtars in the catalogue, may be ſeen the other twelve ſtars, when they are ſhining over the heads of the inhabitants of all the other countries therein named.

453. This conſtitutes the ſyſtem of aſtronomical geography before ſpoken of. It affords us a real aſſiſtance from the heavens, whereby we not only ſee the marvellous diſtances of a multitude of celeſtial bodies, compoſing that part of the univerſe which we are permitted to behold; but it alſo enables us to comprehend the diſtances and bearings of the moſt remote countries from that point of the earth upon which we ſtand.

EXAMPLE II.

454. When the bright ſtar marked *β*, in the head of caſtor, is upon the meridian of London with the 110th degree of right aſcenſion, the twelve following correſpondents will be vertical to the places annexed.

Weſtward.

Weſtward.

Rigt. Aſc.		Dec. and Lat.			Lon. W.
14	Girdle of Andromeda, Mizar	β	34	Kichuans, Louiſiana	96
18	Caſſiopea's thigh	δ	59	P. Walesfort, Hudſons Bay	92
27	Almaak, foot of Andromeda	γ	41	Twightees, S. of Lake Michigan	83
42	Shoulder of Perſeus	γ	52	Eſkimos between L. Otter and L. Pitetibi, North America	68
47	Algenib, Perſeus's ſide	α	49	Cape Riſher, G. St. Lawrence	63
76	Rigel, Orion's foot	β	9	Sea and Coaſt of Olinda	34

Eaſtward.

Rigt. Aſc.		Dec. and Lat.			E. Lon.
132	Great Bear's foot	κ	47	Middle of Hungary	22
139	Hydra's heart	α	8	Kingdom Maſſey, Africa	29
143	Corner of the Lyon's mouth	ε	25	Nahaſſa, in Egypt	33
149	Regulus, Lyon's heart	α	13	Abyſſinia, Africa	39
176	Third in the Sq. Great Bear	γ	55	Oſtiakis, S. W. part of Siberia	66
192	N. Wing of Virgo, Vindematrix	ε	12	Sea 2° E. of Pondicherry	82

Theſe ſtars are viſible in the months of January, February, and March.

EXAMPLE III.

455. When the bright ſtar marked α in the ear of corn, which the virgin holds in her hand, called ſpica virginis, is upon the meridian of London with 198 degrees of right aſcenſion, the following twelve ſtars will be vertical to the ſeveral places in the following table.

Weſtward.

Rig^{t}. Aſc.		Decl. and Lat.			W. Lon.
90	Firſt ſtar in the foot of Caſtor	η	$22\frac{1}{2}$	Iſles of Tres Marias, New Spain	108
113	Head of Pollux	β	29	Sea near C. Eſcondid, Florid.	85
139	Hydra's heart	α	$7\frac{1}{2}$	Yamari, a Branch of the Amazorian River	61
149	Regulus, Lyon's heart	α	13	Sea 12° E. of the Antilles	49
175	Lyon's tail, Alaſad	β	16	Near Bonaviſta, C. Verd Iſles	23
191	Firſt in tail Great Bear, Alioth	ε	57	Weſtern Iſles of Scotland	7

Eaſtward.

Eaſtward.

Rig^{t}. Aſc.		Decl. and Lat.			E. Lon.
212	N. Hand of Bootes	ι	52	S. of Berlin, in Pruſia	14
243	Scorpion's heart	α	25	S. Coaſt of Madagaſcar	45
249	In the Back of Hercules	η	39	S. Eaſt of the Caſpian Sea	51
277	Vega, in Lyra	α	39	Coten, in Tartary	79
290	Albiero, the Swan's beak	β	28	Toudſang, in Thibet Major	92
294	Atair, in the Eagle	α	8	Eaſtern Sea, or Coaſt of Mallocca	96

This phenomenon may be ſeen in the months of April, May, and June.

EXAMPLE IV.

456. When the 289th degree of right aſcenſion is upon the meridian of London, ſignified by one minute of an hour after the ſtar marked δ in the ſouthern wing of the eagle has paſſed the meridian, then the twelve following places will have the annexed ſtars in their zenith.

Weſtward.

Rigt. Aſc.			Dec. and Lat.		W. Lon.
206	The ſtar in the leg of Bootes	η	20	Sea 2° S. Cape Corrente, Cuba	83
219	Southern Scale of Libra	α	15	Collao, in Peru	70
226	Northern Scale of Libra	β	8	Amazonia, America	63
236	A ſtar in Scorpio	π	25	Paragua, America	53
240	Hand of Serpentarius	δ	3	N. W. part of Brazil	49
267	Knee of Hercules	θ	37	N. of St. Michael, in the Azores	22

Eaſtward.

Rigt. Aſc.			Dec. and Lat.		E. Lon.
321	Side of Cepheus	β	70	Fro. Sea near Iſle Wardus, Laponia	32
328	Shoulder of Aquarius	α	1	Between Sio and Ampaia, Zanguebar	39
331	Firſt in the head of Cepheus	ε	56	Ruſſia, 4° E. of Moſcow	42
343	Markab in Pegaſus	α	27	Sea Coaſt, in Perſian Gulph	54
359	Andromeda's head	δ	27	Tala, Mogul's Empire	70
360	A ſtar in Pegaſus	γ	14	Sea near Iſle Lakdinas	71

Theſe ſtars may be obſerved in the months of July, Auguſt, and September.

EXAMPLE

EXAMPLE V.

457. When the ſtar marked θ in the ſide of the whale is upon the meridian of London, with 18 degrees of right aſcenſion, the twelve following ſtars will be in the zenith of the annexed places.

Weſtward.

Rigt. Aſc.		Dec. and Lat.			W. Lon.
290	The Swan's beak	β	28	Gulph Mexico, 30 S. Miſiſipi	88
294	Firſt in the Swan's wing	δ	44	Lake Michigan, Canada	84
308	Deneb, in the Swan's rump	α	44	New England	70
324	Side of Cepheus	β	70	Cumberland near Baffin's Bay	57
331	Head of Cepheus	ε	56	N. Sea, E. of Labrador	47
341	Fomahaut, mouth of Piſces Notius	α	30	Middle of the Atlantic Ocean	37

Eaſtward.

Rigt. Aſc.		Dec. and Lat.		E. Lon.
27	Almaak, foot of Andromeda	γ 41	Sea coaſt of Sardinia	9
42	Shoulder of Perſeus	γ 52	Briſac Luthania	24
43	Menkar, Whale's mouth	α 3	Bake Bake, Africa	25
53	The Pleadies	23	Frontiers of Egypt and Nubia	35
96	North foot of Pollux	γ 16	Golconda, Aſia	78
112	Procyon, little Dog	α 6	Sea 1°N.W.Achem Summatra	94

The ſtars in this example may be ſeen in the months of October, November, and December.

PROBLEM LII.

The phenomena of the harveſt moon.

458. When the moon is at or near the full about the time of an autumnal equinox, ſhe riſes nearly at the ſame hour for ſeveral nights together, which phenomenon is called the *harveſt moon.*

To account for this upon the celeſtial globe, ſet the artificial ſun upon the firſt point of libra, where the ſun muſt neceſſarily be at every autumnal equinox, and place the artificial moon upon the firſt point of aries, where ſhe muſt be if a full moon ſhould happen at that time.

459. Rectify the globe to the poſition of a right ſphere, art. 234. which anſwers to the inhabitants of the equator; bring the center of the artificial ſun to the weſtern edge of the broad-paper circle, and the horary index in this caſe being the graduated edge of the ſtrong braſs meridian, will cut the time of the ſun's ſetting, and the moon's riſing; hence it is obvious the moon will riſe when the ſun ſets, which will be at VI o'clock, becauſe they are both ſuppoſed to be in the celeſtial equator, but in oppoſite ſigns. Therefore on that day the ſame phenomenon will happen in all latitudes between the equator and either pole.

460. But as the moon's motion in her orbit, which we ſhall at preſent conſider as coincident with the ecliptic, is about 13 deg. 10 min. every day, which retards her diurnal motion about 51 min. 56 ſec. of time

with reſpect to the firſt point of aries, this daily difference as it relates to the ſun is generally reckoned at 48 minutes of time, or two minutes for every hour.

461. Let us now enquire upon the globe, what time the moon will riſe the next night after the autumnal equinox, at which time the ſun will have advanced one degree in libra, and the moon 13 deg. 10 min. in aries, which is 12 degrees more than the ſun has done in the ſame time, therefore place the center of the artificial ſun upon the firſt degree of libra, and the artificial moon on 13 deg. 10 min. of aries, the globe being rectified as before to the poſition of a right ſphere, bring the artificial ſun under the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to XII, turn the globe until the artificial ſun coincides with the weſtern ſide of the broad-paper circle, the horary index will ſhew he ſets that evening at VI o'clock, and the globe being turned till the artificial moon coincides with the eaſtern ſide of the broad-paper circle, the horary index will ſhew the moon's riſing that evening to be about 48 minutes paſt VI o'clock, with 5 degrees of amplitude

northerly, as ſhe is now entered into the northern half of the ecliptic.

462. Now elevate the north pole of the globe to the latitude of London, every other rectification remaining the ſame, and bring the artificial moon to the eaſt ſide of the horizon, and the horary index will point to 20 minutes paſt VI, her time of riſing and her amplitude at that time will be about 8 degrees, three degrees more than at the equator the ſame evening.

463. If we thus inveſtigate the time of the moon's riſing for two or three nights together before and after the autumnal full moon, it will be found nearly the ſame.

464. The reaſon is that the full moons which happen at this time of the year, are aſcending from the ſouthern into the northern ſigns of the zodiac, whence the moon deſcribes a parallel to the equator every night more northerly, which increaſes her riſing amplitudes conſiderably, and more ſo as the latitude is greater, as in the preſent example; hence it is plain the nearer any celeſtial object is to either pole, the ſooner it aſcends the horizon.

465. Every thing remaining as before if we elevate the north pole of the globe to 66½ degrees, which is the latitude of the northern polar circle, and bring the artificial moon to the eaſt ſide of the horizon, ſhe will be found to riſe about the ſame time that the ſun ſets the evening after the autumnal full moon, which is about VI o'clock, at which time and place her amplitude will be about 13 degrees.

466. In this poſition of the globe if the artificial moon be removed 13 deg. 10 min. upon the ecliptic, which is her mean motion therein for one day, and ſo on for fourteen nights together, ſhe will be ſeen to riſe within the ſpace of one hour during that time, which will be clear on obſerving that half the ecliptic riſes at once.

467. It is remarkable that when the moon varies leſt in the time of her riſing, the diurnal differences are greateſt at the times of her ſetting.

What has been ſaid with reſpect to north latitudes is equally applicable to ſouth latitudes.

468. In like manner the new moons in ſpring riſe nearly at the ſame hour for

ſeveral nights ſucceſſively, while the full moons riſe later by a greater difference than at any other time of the year, becauſe at this time of the year the new moons are in the aſcending, and the full moons in the deſending ſigns.

469. This phenomenon varies in different years, the moon's orbit being inclined to the ecliptic about 5 degrees, and the line of nodes continually moving retrograde, the inclination of her orbit to the equator will be greater ſometimes than at others, which prevents her haſtening to the northward or deſcending ſouthward in each revolution with equal pace.

PROBLEM LIII.

To find the time of the year in which a ſtar riſes or ſets coſmically or achronically.

470. The coſmical riſing and ſetting of a ſtar, is when a ſtar riſes with the ſun, or ſets at the time the ſun is riſing.

Elevate the pole of the celeſtial globe to the latitude of the place, and bring the ſtar to the eaſtern edge of the broad-paper circle, and obſerve what degree of the ecliptic riſes with it, which ſeek in the kalendar on the broad-paper circle, againſt which is the day of the month when that ſtar riſes coſmically.

Turn the globe till the ſtar coincides with the weſtern edge of the horizon, and that degree of the ecliptic which is cut by the eaſtern ſide, gives the day of the month when the ſtar ſets coſmically; ſo likewiſe againſt the degree which ſets with the ſtar you have the day of the month of its acronical ſetting, and if you bring it to the eaſtern ſide of the horizon, that degree of the ecliptic then cut by the weſtern ſide of the broad-paper circle ſought in the kallendar, will ſhew the day of the month when the ſtar riſes achronically.

PROBLEM

PROBLEM LIV.

To find the time of the heliacal riſing and ſetting of a ſtar.

471. Elevate the pole of the celeſtial globe to the latitude of the place, bring the ſtar to the eaſtern ſide of the broad-paper circle, fix the quadrant of altitude to the zenith, and apply its graduated edge to the weſtern ſide in ſuch a manner that its 12th degree above the horizon may cut the ecliptic, the point oppoſite to this will be 12 degrees below the broad-paper circle on the eaſtern ſide, and is the ſun's place in the ecliptic at the time a ſtar of the firſt magnitude riſes heliacally, ſeek this point in the kalendar, or upon the ecliptic line on the globe, againſt which you will find the day of the year when that ſtar riſes heliacally.

To find the heliacal ſetting bring the ſtar to the weſtern ſide of the horizon, and turn the quadrant of altitude on the eaſtern ſide till the 12th degree cuts the ecliptic, its oppoſite point is the ſun's place, which ſought either upon the kalendar or ecliptic line, gives the day of the year when the ſtar ſets heliacally.

Stars of the firſt magnitude, according to Ptolemy, riſe or ſet heliacally when they are 12 degrees diſtant from the ſun, that is when the ſtar is riſing the ſun muſt be depreſſed in the perpendicular below the horizon 12 degrees, that the ſtar may be far enough from the ſun's rays to be ſeen before he riſes.

Stars of the ſecond magnitude require the ſun's depreſſion thirteen degrees, and thoſe of the third magnitude fourteen degrees, &c.

The manazil al kamer of the Arabian aſtronomers, from Ulugh Beigh, publiſhed at Oxford 1665.

472. The manazil al kamer of the Arabian aſtronomers, are XXVIII, they are ſo called, i. e. the manſions of the moon, becauſe they obſerved the moon to be in or near one of theſe every night during her monthly courſe round the earth, they are theſe that follow, to which upon the globe

the Arabian characters are affixed, but omitted here for the want of an Arabian type.

I. *Al Sheratân*, theſe are the firſt and ſecond ſtars of aries, or the ſtars in the rams horns, marked β and γ, with I, ☾, ſignifying the firſt manſion of the moon, which the reader will pleaſe to remember once for all.

II. *Botein* the ſtars in the rams belly according to Ulugh Beigh, by Bayer and on our globe ε and ρ

III. *Al Thuraiga*, the pleiades.

IV. *Al Debarân*, the bull's eye.

V. *Al Heb'a*, the three ſtars in the head of orion.

VI. *Al Hen'ah*, the ſtar marked ξ in the left foot of pollux.

VII. *Al Dira*, the two bright ſtars, one in the head of caſtor, the other in pollux, marked α and β.

VIII. *Al Nethrah*, the nebulæ or group of ſtars in cancer, marked ε called by the Greeks φᾶτνη, i. e. præſepe.

IX. *Al Terphah*, the lyon's eye marked μ.

X. *Al Geb'ha*, the ſtar in the lyon's main marked ζ.

XI. *Al Zub'rah*, the ſtars in the lyon's rump marked δ and θ.

XII. *Al Serphah*, the lyon's tail marked β, called deneb al aſad.

XIII. *Al Awwa*, they are four ſtars in virgo marked η δ θ γ.

XIV. *Simák al A'zal*, the virgin's ſpike marked α.

XV. *Al Gaphr*, three ſtars in the ſkirt of the robe of virgo marked φ ι κ.

XVI. *Al Zubàna*, that is libra, the northern ſcale is called *Zubânah Al Shemali*, and is the ſtar marked β, the ſouthern ſcale marked α, is called *Zubânah al Genubi*, ſhemali ſignifies northern, and genubi ſouthern, they are exactly miſcalled on the common globes of modern conſtruction.

XVII. *Al-Iclîl*, theſe are the four ſtars in ſcorpio marked ν β δ π.

XVIII. *Al Kalb*, the ſcorpion's heart marked α more fully. *Kalb Al Akrab*, the word *Antares*, if it is not a corruption, has no ſignification, and is therefore omitted.

XIX. *Al Shaulah*, the ſcorpion's tail, or the ſtar marked λ. The word *Leſath* we have omitted, being another pronunciation of *Lâſah*, the true name is *Shaulah*.

XX. *Al Nâaim*, theſe are eight ſtars in ſagittary, marked γ δ ε λ μ σ φ ψ; Ulugh Beigh makes them only three, i. e. γ σ ψ.

XXI. *Al Beldah*, this is that part of the horſe in ſagittary where there are no ſtars drawn, and if there be any in that part of the heavens, it is thought they are only teleſcopic ſtars.

XXII. *Sad Al Dâbih*, three ſtars in capricorn, marked α β ν.

XXIII. *Sad Al Bula*, the ſtar marked ν in the hand of aquarius.

XXIV. *Sad Al Suûd*, the ſtars marked β and ζ in aquarius.

XXV. *Sad Al Achbigah*, three ſtars in aquarius marked γ ξ θ.

XXVI. *Al Pherg al Muhaddem*, the ſtars marked α and β in pegaſus.

XXVII. *Al Pherg al Muâechir*, theſe are two ſtars, one in the head of Andromeda, marked δ, the other in the wing of pegaſus, marked γ.

XXVIII. *Al Riſhâ*, the ſtar marked β in the girdle of Andromeda.

Theſe are a diviſion of the heavens, different from any thing the Greeks were acquainted with, and therefore was not borrowed from them.

PROBLEM LV.

To find a meridian line.

473. Bring the ſun's place in the ecliptic on the celeſtial globe, to the graduated ſide of the ſtrong braſs meridian, and ſet the horary index to that XII. which is moſt elevated; turn the globe, till the ſtar marked γ in Caſſiopea's hip, is under the graduated ſide of the ſtrong braſs meridian, with about 11 degrees of right aſcenſion, at which time the polar ſtar, in the extremity of the tail of the little bear, will be above the pole, and upon the meridian alſo. If you find in this application of the globe, that the horary index points to any hour of the day, when the globe is rectified to the latitude of your ſituation, turn the globe again, till the ſtar marked ε, called Alioth, being the firſt in the tail of the great bear, is under the graduated ſide of the ſtrong braſs meridian, and then the polar ſtar will likewiſe be upon the meridian, with about 191 degrees of right aſcenſion, but under the north pole, and the horary index will

point

point out the time of the night when this phenomenon is to happen, before which you are to have the following apparatus properly prepared, that you may be ready to attend the obſervation, that is, to find your meridian line.

Suſpend two plumb lines, and let their weights be immerſed in water, to prevent their vibrating, but in ſuch a manner that the ſtring of one of them may be directly between the polar ſtar and the ſtring of the other. After this adjuſtment of the two ſtrings, if they remain untouched till the next day at noon, a meridian line may be obtained at any window in the houſe which has a ſouthern aſpect, by ſuſpending lines as above from the ceiling, that next the window may be fixed, but the other ſhould be moveable in a direction nearly eaſt and weſt, the weights of theſe ought alſo to be immerſed in water; then, if two perſons attend a little before noon on the next day, one of them at the two firſt plumb lines which were adjuſted to the polar ſtar, and the other at the two plumb lines in the houſe which are then to be adjuſted, each of them holding a ſheet of white paper in their hands, to receive the ſhadow of the two ſtrings caſt thereon by the ſun; the firſt obſerver is to give a ſignal to the ſecond of the inſtant the two ſhadows on his paper are united in one and the ſame line, at which time the ſun will be preciſely upon the meridian. The other obſerver in the houſe is likewiſe to attend with diligence, and as the ſun is coming nearer and nearer to the meridian, he is conſtantly to remove his moveable plumb line, and keep the ſhadows of his two ſtrings always united in one diſtinct ſhadow, that his obſervation may be compleat, when his aſſiſtant gives the definitive ſignal.

474. If this be repeated four or five times, a very accurate meridian line may be obtained, and may be drawn on the window, the floor, or a pavement, by their ſhadow when united by the ſun's rays, and the plumb lines may be occaſionally ſuſpended from two fixed hooks, when you chuſe to obſerve the paſſage of the ſtars a-croſs the meridian.

PROBLEM LVI.

Of the equation of time.

475. As time flows with great regularity, it is impoſſible to meaſure it accurately, and compare its ſeveral intervals wich each other, but by the motion of ſome of the heavenly bodies, whoſe progreſs is as uniform and regular as itſelf.

Ancient aſtronomers looked upon the ſun to be ſufficiently regular for this purpoſe; but by the accurate obſervations of later aſtronomers, it is found that neither the days, nor even the hours, as meaſured by the ſun's apparent motion, are of an equal length on two accounts.

1ſt, A natural or ſolar day of 24 hours, is that ſpace of time the ſun takes up in paſſing from any particular meridian to the ſame again, and one revolution of the earth, with reſpect to a fixed ſtar, is performed in 23 hours, 56 minutes, 4 ſeconds; therefore from the unequal progreſſion of the earth through her ecliptical orbit, as ſhe takes almoſt eight days more to run through the northern half of the ecliptic, than ſhe does to paſs through the ſouthern, is the reaſon that the length of the day is not exactly equal to the time in which the earth performs its rotation about its axis.

2dly, From the obliquity of the ecliptic to the equator, on which laſt we meaſure time, and as equal portions of one do not correſpond to equal portions of the other, the apparent motion of the ſun would not be uniform; or, in other words, thoſe points of the equator which come to the meridian, with the place of the ſun on different days, would not be at equal diſtances from each other, which as to the time of the ſun's appearing upon the meridian, or ſhewing the time of the day upon a dial, is the ſame as if it had an irregular motion thro' the equator, and therefore cauſes it to render the days unequal among themſelves.

This laſt is eaſily ſeen upon the globe, by bringing every tenth degree of the ecliptic to the graduated ſide of the ſtrong braſs meridian, and you will find that each tenth degree on the equator will not come thither with it, but in the following order from ♈ to ♋, every tenth degree of the ecliptic comes ſooner to the ſtrong braſs meridian than their correſponding 10ths on the equator; thoſe in the ſecond quadrant of the ecliptic, from ♋ to ♎, come later, from ♎ to ♑ ſooner, and from ♑ to aries later, whilſt thoſe at the beginning of each quadrant come to the meridian at the ſame time; therefore the ſun and clock would be equal at theſe four times, if the ſun was not longer in paſſing through one half of the ecliptic than the other, and theſe two inequalities joined together, compoſe that difference which is called the equation of time.

476. Theſe cauſes are independent of each other, ſometimes they agree, and at other times are contrary to one another.

477. The time marked out by a uniform motion, is called true time, and that ſhewn by the ſun, is called apparent or ſolar time, and their difference is the equation of time.

478. We now proceed to ſhew how the terreſtrial globe will repre-

ſent the real phenomena relating to the earth, when actually compared with the refulgent rays emitted from the great ſphere of day.

479. The meridians on our new terreſtrial globes, being ſecondaries to the equator, are alſo hour circles, and are marked as ſuch with roman figures under the equator, and at the polar circles. But obſerve, there is a difference in the figures placed to the ſame hour circle; if it cuts the IIId hour upon the polar circles, it will cut the IXth hour upon the equator, which is ſix hours later, and ſo of all the reſt.

480. Through the great Pacific ſea, and the interſection of libra, is drawn a broad meridian from pole to pole, it paſſes thro' the XIIth hour upon the equator, and the VIth hour upon each of the polar circles; this hour circle is graduated into degrees and parts, and numbered from the equator towards either pole.

481. There is another broad meridian paſſing through the Pacific ſea, at the IXth hour upon the equator, and the IIId hour

upon each polar circle; this contains only one quadrant, or 90 degrees, the numbers annexed to it begin at the northern polar circle, and end at the tropic of capricorn.

482. Here we muſt likewiſe obſerve, there are 23 concentric circles drawn upon the terreſtrial globe within the northern and ſouthern polar circles, which for the future we ſhall call *polar parallels*; they are placed at the diſtance of one degree from each other, and repreſent the parallels of the ſun's declination, but differently to what the 47 parallels between the tropics do.

483. The following problems require the globe to be placed upon a plane that is level, or truly horizontal, which is eaſily attained, if the floor, pavement, gravel-walk in the garden, &c. ſhould not happen to be horizontal.

484. A flat ſeaſoned board, or any box which is about two feet broad, or two feet ſquare, if the top be perfectly flat, will anſwer the purpoſe, the upper ſurface of either may be ſet truly horizontal, by the help of a pocket ſpirit level, or plumb rule, if you raiſe or depreſs this or that ſide by

a wedge or two, as the ſpirit level ſhall direct; if you have a meridian line drawn on the place over which you ſubſtitute this horizontal plane, it may be readily tranſferred from thence to the ſurface juſt levelled; this being done, we are prepared for the ſolution of the following problems.

PROBLEM LVII.

To obſerve the *ſun's* altitude by the terreſtrial globe, when he ſhines bright, or when he can but juſt be diſcerned through a cloud.

485. Conſider the ſhade of extuberancy, which is that cauſed by the ſphericity of the globe, heretofore called the edge of the earth's enlightened diſc, and there repreſented by the broad paper-circle, but here reallized by the natural light of the *ſun* himſelf.

Elevate the north pole of the globe to 66 ½ degrees, bring that meridian or hour circle, which paſſes through the IXth hour upon the equator, under the graduated ſide of the ſtrong braſs meridian, the globe being now ſet upon the horizontal plane; turn it about thereon, frame and all, that the ſhadow of the ſtrong braſs meridian may fall directly under itſelf, or in other words, that the ſhade of its graduated face may fall exactly upon the aforeſaid hour circle; at that inſtant the ſhade of extuberancy will touch the true degree of the ſun's altitude upon that meridian, which paſſes through the IXth hour upon the equator, reckoned from the polar circle, the moſt elevated part of which will then be in the zenith of the place where this operation is performed, and is the ſame whether it ſhould happen to be either in north or ſouth latitude.

486. Thus we may, in an eaſy and natural manner, obtain the altitude of the ſun, at any time of the day, by the terreſtrial globe; for it is very plain, when the ſun riſes, he bruſhes the zenith and nadir of the globe by his rays, and as he always illuminates half of it, (or but a few minutes more, as his globe is conſiderably larger than that of the earth) therefore when the ſun

is riſen a degree higher, he muſt neceſſarily illuminate a degree beyond the zenith, and ſo on proportionably from time to time.

But as the illuminated part is ſomewhat more than half, deduct 13 minutes from the ſhade of extuberancy, and you have the ſun's altitude with tolerable exactneſs.

If you have any doubt how far the ſhade of extuberancy exactly reaches, hold a pin, or your finger, on the globe, between the ſun and point in diſpute, and where the ſhade of either is loſt, will be the point ſought.

487. When the ſun does not ſhine bright enough to caſt a ſhadow.

Turn the meridian of the globe toward the ſun, as before, or direct it ſo that it may lie in the ſame plane with him, which may be done if you have but the leaſt glimpſe of the ſun through a cloud; hold a ſtring in both hands, it having firſt been put between the ſtrong braſs meridian and the globe, ſtretch it at right angles to the meridian, and apply your face near to the globe, moving your eye lower and lower, till you can but juſt ſee the *ſun*, then bring the ſtring held as before to this point upon the globe, that it may juſt obſcure the ſun from your ſight, and the degree on the aforeſaid hour circle, which the ſtring then lies upon, will be the ſun's altitude required, for his rays would ſhew the ſame point if he ſhone out bright.

Note. The moon's altitude may be obſerved by either of theſe methods, and the altitude of any ſtar by the laſt of them.

PROBLEM LVIII.

To place the terreſtrial globe in the ſun's rays, that it may repreſent the natural poſition of the earth, either by a meridian line, or without it.

488. If you have a meridian line, ſet the north and ſouth points of the broad-paper circle

directly over it, the north pole of the globe being elevated to the latitude of the place, and ſtanding upon a level plane, bring the place you are in under the graduated ſide of the ſtrong braſs meridian, then the poles and parallel circles upon the globe will, without ſenſible error, correſpond with thoſe in the heavens, and each point, kingdom, and ſtate, will be turned towards the real one which it repreſents.

489. If you have no meridian line, then by knowing the day of the month, find the ſun's declination as before directed, which will direct you to the parallel of the day, amongſt the polar parallels, reckoned from either pole towards the polar circle; which remember.

Set the globe upon your horizontal plane in the ſun-ſhine, and put it nearly north and ſouth by the mariner's compaſs, it being firſt elevated to the latitude of the place, and the place itſelf brought under the graduated ſide of the ſtrong braſs meridian, then move the frame and globe together, till the ſhade of extuberancy, or term of illumination, juſt touches the polar parallel for the day, and the globe will be ſettled as before; and if accurately performed, the variation of the magnetical needle will be ſhewn by the degree it points to in the compaſs box.

490. And here obſerve, if the parallel for the day ſhould not happen to fall on any one of thoſe drawn upon the globe, you are to eſtimate a proportionable part between them, and reckon that, the parallel of the day. If we had drawn more, the globe would have been confuſed.

491. The reaſon of this operation is, that as the ſun illuminates half the globe, the ſhade of extuberancy will conſtantly be 90 degrees from the point where the ſun is vertical.

492. If the ſun be in the equator, the ſhade and illumination muſt terminate in the poles of the world, and when he is in any other diurnal parallel, the terms of illumination muſt fall ſhort of, or go beyond either pole, as many degrees as the parallel which the ſun deſcribes that day, is diſtant from the equator; therefore when the ſhade of extuberancy touches the polar parallel for the day, the artificial globe will be in the ſame poſition, with reſpect

to the ſun, as the earth really is, and will be illuminated in the ſame manner.

PROBLEM LIX.

To find naturally the ſun's declination, diurnal parallel, and his place thereon.

493. The globe being ſet upon an horizontal plane, and adjuſted by a meridian line or otherwiſe, obſerve upon which or between which polar parallel the term of illumination falls, its diſtance from the pole is the degree of the ſun's declination; reckon this diſtance from the equator among the larger parallels, and you have the parallel the ſun deſcribes that day; upon which if you move a card, cut in the form of a double ſquare, until its ſhadow falls under itſelf, you will obtain the very place upon that parallel over which the ſun is vertical at any hour of that day, if you ſet the place you are in under the graduated ſide of the ſtrong braſs meridian.

Note. The moon's declination, diurnal parallel and place, may be found in the ſame manner. Likewiſe when the ſun does not ſhine bright, his declination, &c. may be found by an application in the manner of problem 57.

PROBLEM LX.

To find the ſun's azimuth naturally.

494. If a great circle at right angles to the horizon paſſes through the zenith and nadir, and alſo through the ſun's center, its diſtance from the meridian in the morning or evening of any day, reckoned upon the degrees on the inner edge of the broad-paper circle, will give the azimuth required.

METHOD I.

495. Elevate either pole to the poſition of a parallel ſphere, by bringing the north pole in north latitude, and the ſouth pole in ſouth latitude, into the zenith of the

broad-paper circle, having firſt placed the globe upon your meridian line, or by the other method before preſcribed; hold up a plomb line ſo that it may paſs freely near the outward edge of the broad-paper circle, and move it ſo that the ſhadow of the ſtring may fall upon the elevated pole, then caſt your eye immediately to its ſhadow on the broad-paper circle, and the degree it there falls upon is the ſun's azimuth at that time, which may be reckoned from either the ſouth or north points of the horizon.

METHOD II.

496. If you have only a glimpſe, or faint ſight of the ſun, the globe being adjuſted as before, ſtand on the ſhady ſide, and hold the plomb line on that ſide alſo, and move it till it cuts the ſun's center, and the elevated pole at the ſame time, then caſt your eye towards the broad-paper circle, and the degree it there cuts is the ſun's azimuth, which muſt be reckoned from the oppoſite cardinal point.

PROBLEM LXI.

To ſhew that in ſome places of the earth's ſurface, the ſun will be twice on the ſame azimuth in the morning, and twice on the ſame azimuth in the afternoon; or in other words,

When the declination of the ſun exceeds the latitude of any place, on either ſide of the equator, the ſun will be on the ſame azimuth twice in the morning, and twice in the afternoon.

497. Thus, ſuppoſe the globe rectified to the latitude of Antego, which is in about 17 deg. of north latitude, and the ſun to be in the beginning of cancer, or to have the greateſt north declination, ſet the quadrant of altitude to the 21ſt degree north of the eaſt in the horizon, and turn the globe upon its axis, the ſun's center will be on that azimuth at 6 h. 30 min. and alſo at 10 h. 30 min. in the morning. At 8 h. 30 min. the ſun will be as it were

ſtationary with reſpect to its azimuth for ſome time; as will appear by placing the quadrant of altitude to the 17th degree north of the eaſt in the horizon. If the quadrant be ſet to the ſame degrees north of the weſt, the ſun's center will croſs it twice as it approaches the horizon in the afternoon.

This appearance will happen more or leſs to all places ſituated in the torrid zone, whenever the ſun's declination exceeds their latitude; and from hence we may infer, that the ſhadow of a dial muſt neceſſarily go back ſeveral degrees on the ſame days.

PROBLEM LXII.

To obſerve the hour of the day in the moſt natural manner, when the terreſtrial globe is properly placed in the ſun-ſhine.

498. There are many ways to perform this operation with reſpect to the hour, three of which are here inſerted, being

general to all the inhabitants of the earth; a fourth is added peculiar to thoſe of London, which will anſwer without ſenſible error at any place not exceeding the diſtance of 60 miles from this capital.

1ſt, By a natural ſtile.

Having rectified the globe as before directed, and placed it upon an horizontal plane over your meridian line, or by the other method, hold a long pin upon the illuminated pole in the direction of the polar axis, and its ſhadow will ſhew the hour of the day amongſt the polar parallels.

The axis of the globe being the common ſection of the hour circles, is in the plane of each, and as we ſuppoſe the globe to be properly adjuſted, they will correſpond with thoſe in the heavens; therefore the ſhade of the pin, which is the axis continued, muſt fall upon the true hour circle.

2dly, By an artificial ſtile.

499. Tie a ſmall ſtring with a nooſe round the elevated pole, ſtretch its other end beyond the globe, and move it ſo that the ſhadow of the ſtring may fall upon the depreſſed axis, at that inſtant its ſhadow upon the equator will give the ſolar hour to a minute.

500 But remember, that either the autumnal or vernal equinoctial colure muſt firſt be placed under the graduated ſide of the ſtrong braſs meridian before you obſerve the hour, each of theſe being marked upon the equator with the hour XII.

501. The ſtring in this laſt caſe being moved into the plane of the ſun, correſponds with the true hour circle, and conſequently gives the true hour.

3dly, Without any ſtile at all.

502. Every thing being rectified as before, look where the ſhade of extuberancy

cuts upon the equator, the colure being under the graduated ſide of the ſtrong braſs meridian, and you obtain the hour in two places upon the equator, one of them going before, and the other following the ſun.

503. *Note.* If this ſhade be dubious, apply a pin or your finger as before directed.

504. The reaſon is, that the ſhade of extuberancy being a great circle, cuts the equator in half, and the ſun, in whatſoever parallel of declination he may happen to be, is always in the pole of the ſhade, conſequently the confines of light and ſhade will ſhew the true hour of the day.

4thly, Peculiar to the inhabitants of London, and its environs, within the diſtance of ſixty miles.

The globe being every way adjuſted as before, and London brought under the graduated ſide of the ſtrong braſs meridian, hold up a plomb line, ſo that its ſhadow may fall upon the zenith point, (which in this caſe is London itſelf) and the ſhadow of the ſtring will cut the parallel of the day upon that point to which the ſun is then vertical, and that hour circle this interſection falls upon, is the hour of the day; and as the meridians are drawn within the tropics at 20 minutes diſtance from each other, the point cut by the interſection of the ſtring upon the parallel of the day, being ſo near the equator, may, by a glance of the obſerver's eye, be referred thereto, and the true time obtained to a minute.

The plomb line thus moved is the azimuth, which by cutting the parallel of the day, gives the ſun's place, and conſequently the hour circle which interſects it.

From this laſt operation reſults a corollary, that gives a ſecond way of rectifying the globe to the ſun's rays.

If the azimuth and ſhade of the illuminated axis agree in the hour when the globe is rectified, then making them thus to agree muſt rectify the globe.

COROLLARY.

COROLLARY.

Another method to rectify the globe to the ſun's rays.

505. Move the globe till the ſhadow of the plomb line, which paſſes through the zenith, cuts the ſame hour on the parallel of the day, as the ſhade of the pin held in the direction of the axis falls upon, amongſt the polar parallels, and the globe is rectified.

506. The reaſon is, that the ſhadow of the axis repreſents an hour circle, and by its agreement in the ſame hour, which the ſhadow of the azimuth ſtring points out, by its interſection on the parallel of the day, therefore the ſun is in the plane of the ſaid parallel; which can never happen in the morning on the eaſtern ſide of the globe, nor in the evening on the weſtern ſide of it, but when the globe is rectified.

507. This rectification of the globe, is only placing it in ſuch a manner that the principal great circles, and points, may concur and fall in with thoſe of the heavens.

The many advantages ariſing from theſe capital problems relating to the placing of the globe in the ſun's rays, an intelligent reader will eaſily diſcern, and readily extend to his own as well as to the benefit of his pupil.

A TABLE of Retroceſſion and Autumnal Equinoxes.

Retroceſſion.				Autumnal Equinoxes.		
Years.	D.	H.	M.	Days.	H.	M.
6000	45	20	0	2191454	4	0
5000	38	4	40	1826211	19	20
4000	30	13	20	1460969	10	40
3000	22	22	0	1095727	2	0
2000	15	6	40	730484	17	20
1000	7	15	20	365242	8	40
900	6	21	0	328718	3	0
800	6	2	40	292193	21	20
700	5	8	20	255669	15	40
600	4	14	0	219145	10	0
500	3	19	40	182621	4	20
400	3	1	20	146096	22	40
300	2	7	0	109572	17	0
200	1	12	40	73048	11	20
100	0	18	20	36524	5	40
90	0	16	30	32871	19	30
80	0	14	40	29219	9	20
70	0	12	50	25566	23	10
60	0	11	0	21914	13	0
50	0	9	10	18262	2	50
40	0	7	20	14609	16	40
30	0	5	30	10957	6	30
20	0	3	40	7304	20	20
10	0	1	50	3652	10	10
9	0	1	39	3287	4	21
8	0	1	28	2921	22	32
7	0	1	17	2556	16	43
6	0	1	6	2191	10	54
5	0	0	55	1826	5	5
4	0	0	44	1460	23	16
3	0	0	33	1095	17	27
2	0	0	22	730	11	38
1	0	0	11	365	5	49

A TABLE of Months.

Literal Characters.	Days in each Month.		Days à Kal. Jan.
A	31	January	31
D	28	February	59
D	31	March	90
G	30	April	120
B	31	May	151
E	30	June	181
G	31	July	212
C	31	Auguſt	243
F	30	September	273
A	31	October	304
D	30	November	334
F	31	December	365

A TABLE of Week-Days.

4	Monday
5	Tueſday
6	Wedneſday
0	Thurſday
1	Friday
2	Saturday
3	Sunday

A TABLE of the *Horary Difference* in the Motion of the firſt Point of Aries, at the Time of a Vernal Equinox.

M.	S.	'''	M.	S.	'''
H.	M.	S.	H.	M.	S.
1	0	9	31	4	42
2	0	18	32	4	51
3	0	27	33	5	0
4	0	36	34	5	9
5	0	45	35	5	18
6	0	54	36	5	27
7	1	4	37	5	36
8	1	13	38	5	45
9	1	22	39	5	54
10	1	31	40	6	3
11	1	40	41	6	12
12	1	49	42	6	21
13	1	58	43	6	31
14	2	6	44	6	40
15	2	16	45	6	49
16	2	25	46	6	58
17	2	34	47	7	7
18	2	43	48	7	16
19	2	53	49	7	25
20	3	2	50	7	34
21	3	11	51	7	43
22	3	20	52	7	52
23	3	29	53	8	0
24	3	38	54	8	8
25	3	47	55	8	17
26	3	56	56	8	25
27	4	4	57	8	35
28	4	12	58	8	45
29	4	22	59	8	55
30	4	32	60	9	5

A TABLE of the Difference of the Paſſage of the firſt Point of Aries over the Meridian, for every Day in the Year.

I.

Days	January.			February.			March.			Days
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	5	10	53	2	58	46	1	9	50	
2		6	28		54	42		6	7	1
3		2	4		50	39		2	24	2
4	4	57	40		46	37	0	58	41	3
5		53	16		42	36		54	58	4
6		48	53		38	36		51	16	5
7		44	31		34	36		47	34	6
8		40	9		30	37		43	52	7
9		35	47		26	39		40	11	8
10		31	26		22	42		36	30	9
11		27	6		18	45		32	50	10
12		22	46		14	50		29	10	11
13		18	27		10	55		25	31	12
14		14	9		7	1		21	52	13
15		9	51		3	7		18	13	14
16		5	33	1	59	14		14	34	15
17		1	17		55	22		10	55	16
18	3	57	2		51	32		7	16	17
19		52	47		47	42		3	38	18
20		48	33		43	52	0	0	0	19
21		44	19		40	3	23	56	22	20
22		40	6		36	14		52	44	21
23		35	54		32	26		49	6	22
24		34	43		28	39		45	28	23
25		27	33		24	52		41	50	24
26		23	24		21	6		38	12	25
27		19	15		17	20		34	34	26
28		15	7		13	35		30	56	27
29		11	0					27	18	28
30		6	54					23	40	29
31		2	49					20	2	30

II.

Days	April.			May.			June.			Days
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	23	16	24	21	25	12	19	22	28	
2		12	46		21	23		18	22	1
3		9	8		17	33		14	16	2
4		5	29		13	43		10	9	3
5		1	50		9	52		6	2	4
6	22	58	11		6	0		1	55	5
7		54	33		2	8	18	57	48	6
8		50	54	20	58	16		53	40	7
9		47	14		54	23		49	32	8
10		43	35		50	30		45	24	9
11		39	55		46	35		41	15	10
12		36	14		42	40		37	6	11
13		32	33		38	44		32	57	12
14		28	52		34	49		28	48	13
15		25	11		30	51		24	39	14
16		21	30		26	54		20	29	15
17		17	47		22	56		16	20	16
18		14	4		18	58		12	11	17
19		10	21		14	59		8	1	18
20		6	38		11	0		3	51	19
21		2	54		7	0	17	59	42	20
22	21	59	11		2	59		55	33	21
23		55	26	19	58	59		51	23	22
24		51	41		54	58		47	14	23
25		47	55		50	56		43	4	24
26		44	9		46	53		38	55	25
27		40	23		42	50		34	46	26
28		36	36		38	46		30	37	27
29		32	48		34	42		26	29	28
30		29	0		30	38		22	20	29
31					26	33				30

III.

Days	July.			Auguſt.			September.			Days
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	17	18	11	15	13	26	13	17	22	
2		14	3		9	33		13	45	1
3		9	56		5	41		10	8	2
4		5	48		1	49		6	31	3
5		1	41	14	57	58		2	54	4
6	16	57	34		54	8	12	59	17	5
7		53	28		50	18		55	40	6
8		49	22		46	29		52	4	7
9		45	17		42	40		48	28	8
10		41	12		38	52		44	52	9
11		37	7		35	5		41	16	10
12		33	2		31	18		37	40	11
13		28	58		27	32		34	4	12
14		24	55		23	46		30	29	13
15		20	52		20	1		26	54	14
16		16	49		16	16		23	18	15
17		12	47		12	32		19	43	16
18		8	46		8	48		16	7	17
19		4	45		5	5		12	31	18
20		0	45		1	22		8	56	19
21	15	56	45	13	57	40		5	20	20
22		52	46		53	58		1	44	21
23		48	48		50	16	11	58	8	22
24		44	49		46	35		54	32	23
25		40	51		42	55		50	56	24
26		36	54		39	14		47	20	25
27		32	57		35	35		43	44	26
28		29	2		31	55		40	7	27
29		25	6		28	17		36	30	28
30		21	12		24	38		32	53	29
31		17	18		21	0				30

IV.

Days	October.			November.			December.			Days
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	11	29	15	9	32	50	7	28	50	
2		25	37		28	55		24	29	1
3		21	59		24	58		20	8	2
4		18	20		21	0		15	47	3
5		14	42		17	2		11	25	4
6		11	3		13	3		7	3	5
7		7	23		9	3		2	40	6
8		3	43		5	2	6	58	17	7
9		0	2		1	0		53	54	8
10	10	56	21	8	56	57		49	30	9
11		52	40		52	53		45	6	10
12		48	58		48	49		40	41	11
13		45	16		44	44		36	15	12
14		41	33		40	38		31	50	13
15		37	50		36	31		27	24	14
16		34	6		32	23		22	58	15
17		30	21		28	14		18	32	16
18		26	36		24	5		14	5	17
19		22	50		19	54		9	39	18
20		19	4		15	44		5	13	19
21		15	17		11	32		0	46	20
22		11	29		7	19	5	56	19	21
23		7	40		3	5		51	52	22
24		3	51	7	58	51		47	25	23
25		0	2		54	36		42	59	24
26	9	56	11		50	20		38	33	25
27		52	20		46	4		34	6	26
28		48	27		41	47		29	40	27
29		44	34		37	29		25	14	28
30		40	41		33	10		20	48	29
31		36	47					16	23	30

FINIS.

MVSEVM
BRITAN
NICVM